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Paul Salmon
Anne-Claire Macquet *Editors*

Advances in Human Factors in Sports and Outdoor Recreation

Proceedings of the AHFE 2016 International Conference on Human Factors in Sports and Outdoor Recreation, July 27–31, 2016, Walt Disney World®, Florida, USA

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Preface

Human factors in sports and outdoor recreation aims to address the critical cognitive and physical tasks which are performed within a dynamic, complex, and collaborative system comprising multiple humans and artifacts, under pressurized, complex, and rapidly changing conditions that take place during the course of any sporting event. Highly skilled, well-trained individuals walk a fine line between task success and failure, with only marginally inadequate task execution leading to loss of the sport event or competition. This conference promotes cross-disciplinary interaction between the human factors in sports and outdoor recreation disciplines and provides practical guidance on a range of methods for describing, representing, and evaluating human, team, and system performance in sports domains. Traditionally, the application of human factors and ergonomics in sports has focused on the biomechanical, physiological, environmental, and equipment-related aspects of sports performance. However, various human factors methods, applied historically in the complex safety critical domains, are suited to describing and understanding sports performance. The conference track welcomes research on cognitive and social human factors in addition to the application of physiological ergonomics approaches sets it apart from other research areas. This book will be of special value to a large variety of professionals, researchers, and students in the broad field of sports and outdoor recreation.

This book will be of special value to a large variety of professionals, researchers, and students in the field of performance who are interested in injury and accidents prevention, and design for special populations, particularly athletes. We hope this book is informative, but even more—that it is thought-provoking. We hope it inspires, leading the reader to contemplate other questions, applications, and potential solutions in creating good designs for all.

We would like to thank the editorial board members for their contributions.

Maroochydore, Australia Paul Salmon
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July 2016

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Part I
Decision Making and Cognition in Sports

Knowledge Elicitation Methods for Developing Insights into Team Cognition During Team Sports

Nathan J. McNeese, Nancy J. Cooke, Rob Gray and Michael Fedele

Abstract Team cognition is beginning to be realized as an important facet of team sports. As we continue to articulate the role of team cognition during team sports, we need to understand how to measure team cognition. In this paper, we present multiple knowledge elicitation methods to measure team cognition. We also propose new elicitation methods that account for the dynamic nature of team sports.

Keywords Team cognition · Knowledge elicitation · Team sports

1 Introduction

As outlined by McNeese et al. [1], the development of team cognition within team sports is critical to effective performance on the field of play. Although a great deal is known about teamwork in sports, little attention has been paid to the concept of team cognition. Team cognition is the cognitive activity that occurs at the team level [2]. Team cognition allows sports teams to link the physical (play on the field) and cognitive (strategy or game plan) demands of sports, effectively implementing them at a team level. As a result, the role and potential of team cognition development can directly impact team performance [3].

To this point, the research community is beginning to realize the potentially important role and impact of team cognition during team sports. Yet, we must move past simply understanding team cognition and team sports at a conceptual level to

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empirically validating theoretical assumptions. Both conceptual and theoretical arguments are important in articulating the relationship between team cognition and team sports, but empirical truth is necessary to confirm theoretical representations.

In order to explicitly and empirically understand the role of team cognition during team sports, more studies linking these concepts to performance data from actual play are needed. In addition, scholars in this field need to understand how to effectively measure team cognition through multiple methodologies. The identification and measurement of team cognition is challenging, but over the years, multiple effective and validated metrics have been developed. More specifically, many of these metrics have revolved around the utilization of *knowledge elicitation* methods. Knowledge elicitation is the "process of collecting from a human source of knowledge, information that is thought to be relevant to that knowledge" [4, p. 802]. Essentially, knowledge elicitation methods allow for researchers to probe humans' cognition. Specific to team cognition, knowledge elicitation can be conducted at both an individual and team level.

In this paper, we present multiple knowledge elicitation methods that are relevant to team cognition in the team sports context. A sampling of the specific methods we will outline and explicitly explain how to utilize within the sports context are: (1) observations and interviews, (2) process tracing, (3) conceptual techniques. For each of these categories, we will present what they are, the many specific ways to utilize each, and an application section connecting each specifically to team sports. These are traditional knowledge elicitation methods that can be adequately used for team sports. Although, with these traditional efforts comes some limitations, most significantly that they are often oriented towards aggregation of individual knowledge. In the team sports context, we need additional elicitation methods that also measure cognitive processing at the team level. In response this this, we present a discussion on the challenges of using traditional knowledge elicitation methods within the the context of sports. Finally, we present a section outlining new knowledge elicitation methods that are more pointed at team level cognitive processing during team sports.

2 Team Cognition in the Literature

Team cognition is cognitive processing that occurs at the level of the team [2]. Over the years, team cognition has provided insight and understanding to the effectiveness of teams [3]. Due to its wide spread prevalence, team cognition has been investigated in many different contexts, with the focus on many specific aspects of team cognition—a few examples include: team training [5], teams with artificially intelligent teammates [6] and the use of collaboration technologies [7].

Historically, team cognition has been viewed from a *shared knowledge perspective*, which suggests that team members have separate mental representations (consisting of specific knowledge) which they share across the team to help make decisions [8, 9]. More recently, an *ecological perspective* has been asserted, which views team cognition purely as a team activity that should be examined at the team level, and is inseparable from the environment in which it exists [2]. The latter perspective has been suggested as being appropriate to apply to the team sports context [1].

The shared knowledge perspective is typically defined and conceptualized by the shared mental models (SMMs) approach. The SMM concept postulates that team members share their individual mental models of taskwork and teamwork knowledge throughout the team to create an overall shared mental model [8, 9]. These shared representations allow teams to plan, process, and respond to typical and novel scenarios [8, 9]. The content of shared knowledge can refer to collective representations of objectives, materials, relationships, and scenarios [10]. It has been found that congruent knowledge among team members is the primary reason for team success [11]. In addition, shared knowledge of a task environment has lead to improved performance in teams [12].

In sports, Reimer and colleagues [13] state that in order for SMMs to be advanced and improved, teammates must be "on the same page." Eccles and Tennenbaum [14] have also noted that athletes have knowledge structures in place which enable predictions and alterations to be made to present and upcoming events. SMMs have been found to exist in hockey and handball players by comparing questionnaires regarding on-court thoughts and behaviors [15]. Professional basketball players have also been retrospectively questioned about their shared knowledge, where it was found that 87 % of the time teammates partially share knowledge, 12 % of the time teammates fully share information, and 1 % of the time teammates are not sharing information at all [16].

The ecological approach asserts that the interactions occurring during teamwork is team cognition [2]. The ecological approach and the theory of Interactive Team Cognition (ITC) are interrelated takes on team cognition. As reviewed by Cooke [17], ITC aligns with modern views of individual cognition, articulating that it can reside outside of the brain, (e.g., embodied cognition or activity theory) [18, 19]. In teams, the ecological perspective asserts that cognition exists in the many behaviors of interaction. In sports, an interaction could be something as explicit as demanding the ball from a teammate, or subtle behaviors, such as, eye contact, winking, or head nodding.

Athletic competition spurs profound changes which can never be fully anticipated. During these novel experiences and perturbations, teammates spawn shared affordances because of synergetic processes [20], therefore, it is possible the ecological perspective may be a more valuable technique for examining teamwork in sports compared to the shared knowledge perspective. This perspective does not suggest that individual cognitive processes do not play a role in teamwork and team interactions. But, the perspective does stress that individual cognition is not observable, while team processes can be reliably examined. ITC does not attempt to abolish shared mental models, it encompasses them. It may be valuable for researchers in this field to begin considering the importance of interactions as they happen. Here may lie the opportunity for the purest observation of teamwork and team cognition in sports.

3 Methods for Studying Team Cognition

Over the past 20 years, many methods for capturing and understanding team cognition have been put forth in the literature. At one point, the research community struggled greatly in understanding how to empirically measure team cognition, mainly because there was still a great deal of misunderstanding regarding the concept itself. But, as the team cognition research community has grown, numerous different methodologies have been developed that allow us to gather data that is directly representative of team cognition.

Most studies related to team cognition have traditionally occurred within the lab using experimental methodologies (see review of shared mental models by [21]). The reasons for this are that the experimental context allows research to isolate for specific aspects of team cognition (such as knowledge, situational awareness, communication and coordination, etc.) in a controlled environment void of confounding variables. In addition, a growing number of laboratory studies are also incorporating aspects of knowledge elicitation to better understand team cognition [22, 23].

Yet, as interest in team cognition grows, researchers are becoming interested in learning about how it occurs in real teams, outside the lab. For these types of studies, knowledge elicitation methods are recommended due to their wide-ranging scope and flexibility. Below, we outline knowledge elicitation and how it should be defined for the team sports context.

3.1 Knowledge Elicitation: A Historical Perspective

Knowledge elicitation methods have long been used in multiple communities (such as human factors, psychology, cognitive science, information sciences, computer sciences, etc.) to understand the cognitive aspects of many different types of work. In general, *knowledge elicitation* refers to "process of collecting from a human source of knowledge, information that is thought to be relevant to that knowledge" [4, p. 802]. The actual process of eliciting knowledge can vary drastically depending on the specific method the researcher is using. Yet, all knowledge elicitation methods are aimed at discovering information and knowledge that is utilized to help one perform a specific action.

Historically speaking, by collecting domain and task relevant knowledge, we can then articulate what a person's cognition is. Traditionally, knowledge has been viewed as a direct outlet for cognition [24]. Referring to the previous section, we can see this notion in action. The concept of a shared mental model is based on knowledge, more specifically team members sharing their relevant taskwork and teamwork related knowledge amongst each other.

Knowing that knowledge is a critical facet of cognition, it is imperative that we understand how to adequately capture and measure knowledge at both an individual and team level. For this reason, knowledge elicitation methods have become a popular mechanism for developing insights into individual and team cognition. Cooke [4] has provided the most comprehensive review of knowledge elicitation methods to date. In this publication, she outlines that knowledge elicitation is generally separated into three distinct families: (1) observations and interviews, (2) process tracing, and (3) conceptual techniques. Within each of these families are multiple other specific methodological techniques. Observations and interviews are self-apparent in their meaning, but process tracing and conceptual techniques are not as pronounced. Process tracing techniques refer to gathering knowledge relevant data while a person performs a task, such as creating a verbal report of what the participant is thinking in concurrence with their actual task performance. Conceptual techniques are used to create representational visualizations that include relevant knowledge (content) and the associated linkages and relationships between direct or indirect information or knowledge.

The researcher must examine the task and the context that they are conducting their research in, and then systematically choose which specific techniques they are going to use for their study. Understanding the context that the research is occurring in, and the pros and cons of each technique is one of the keys to adequately utilizing knowledge elicitation. One could seemingly pick any of these techniques to capture knowledge but if the technique is not aligned with the context or not logistically possible, then the data will be jeopardized. This is why it is important that each of these families is reviewed in accordance with the context of team sports. In addition, when one considers knowledge at the team level, it is important to understand which techniques work best for conceptually and logistically eliciting team cognition. In the next section, we do just that, outlining the details of each family and how they can be applied to a team sports context. First, we further delineate our meaning of knowledge elicitation, expanding its conceptual means to better afford for the team cognition that occurs during team sports.

3.2 A New Conceptualization of Knowledge Elicitation for Team Sports

Traditional knowledge elicitation methods are highly dependent on the aggregation of individual's cognition to then represent team cognition. This perspective is useful depending on the task and context that is being studied. In a setting that is highly dynamic, such as team sports, the focus needs to account for more than just individual aggregation of knowledge. Although individual knowledge is an important facet of team cognition within this setting, there are many other variables that are impacting team cognition. Most notably, cognitive processing occurring at the team level is impactful to team cognition occurring in a dynamic environment. Examples of team level cognitive processing are communication and coordination occurring amongst and within the team. Due to the characteristics of the dynamic environment that team sports occur in, measurements of team cognition need to account as much for team level cognitive processing as individual knowledge aggregation. There is a place for both of these aspects of team cognition to be studied within the context of team sports, yet better metrics representative of team level cognitive processing need to be developed. For this reason, we recommend that knowledge elicitation needs to be conceptually updated to include aspects team level cognitive processing.

This is not to indicate that traditional knowledge elicitation methods are not valuable to the team sports context. In fact, we feel that individual knowledge is important to fully understanding team cognition. In addition, not all knowledge elicitation methods are dependent on individual knowledge aggregation. There are significant opportunities to use traditional knowledge elicitation methods at the team level, which we outline in the next section. The purpose of the rest of this paper is to show how traditional knowledge elicitation methods can be applied to the sports team context, and also outline new knowledge elicitation methods that account for team level cognitive processing. By utilizing traditional knowledge elicitation methods in addition to newer cognitive processing methods, we feel that team cognition can be holistically measured in the context of team sports.

4 Traditional Knowledge Elicitation Methods for Studying Team Cognition in Sports

4.1 Observations and Interviews

Observations and interviews are two of the most popular knowledge elicitation methods, and have been used to elicit knowledge in a variety of different contexts. First, we will discuss observations. Observations are insightful into cognition, as there is a direct link between interactions and cognition. Observations allow us to observe aspects of a human's cognition in real time. Typically, when one is probing for cognition they will go directly to the individual or team of individuals and ask them what they were thinking during a specific instance in time. Although this is an effective means of capturing cognition, humans are often unreliable in describing their own cognition. For this reason, it is valuable to triangulate that data with observable data. Pairing both sets of data together has the potential to strengthen validity. Cooke [4] operationalizes observations into three different varieties: active, focused, and structured. We will not outline each of these in depth, but active participation involves the researcher being a part of the actual observation, whereas focused and structured methods are ways to systematically observe different parts of the environment.

For the team sports context, observations will be very important in helping to understand team cognition. Depending on the sport, there may or may not be active verbalization in the field of play. In addition, specific cognitive probing via interviewing will have to occur retroactively after the sport has concluded. So, observations may be the only real time dataset that can provide insights into how the team is working together. The potential for specifically understanding team coordination (directly linked to team cognition) through observation during the game is apparent by tagging and tracking each player's movements and interactions back and forth with each other.

Interviews are extremely impactful in gaining insight into team cognition. Through an interview, the researcher has the potential to explicitly probe for specific aspects of the team's cognition. There are two ways to utilize interviewing for the purposes of team cognition. First, individual interviews of team members can be conducted and then analyzed (or aggregated) to the team level. This method is adequate as long as the researcher amends the aggregated dataset with a team level dataset (such as observations or process tracing of team level communication). Secondly, interviews may also occur in the form of focus groups where all members of the team are present.

The content and structure of the interviews is dependent on the researchers and can span from unstructured, semi-structured, and structured. The variation in each of these types of interviews is dependent on how focused the interview is. A structured interview would indicate that the researcher has a set of interview questions that they have predetermined to ask the interviewee. Determining what type of interview to conduct is an important consideration, and should be dictated by the goals of the knowledge elicitation. If the researcher is interested in a very specific aspect of knowledge, then a more structured interview may be most appropriate. In general, we recommend semi-structured interviews, as they provide an overarching structure yet also afford additional cognitive probing.

In the team sports context, we see interviews as an important means to articulating team level cognition. Interviews may take place before or after the game and at the level of the individual or the entire team. We recommend that observations are paired with interviews in the sports context. Pairing these two datasets allows for the researcher to ask specific questions related to what was observed during the game.

4.2 Process Tracing

Process tracing refers to data used to make cognitive inferences aligned with task performance [4]. There are multiple specific process tracing methods, but for the purposes of this paper we will focus on verbal reports. Verbal reports are viewed as a direct dialogue into cognition and knowledge. A verbal report is classified by being online or offline [4]. An online report indicates that the individual or team of individuals are actively and concurrently verbalizing what they are thinking while performing a specific activity. An example of online reporting is the think aloud method. Whereas, an offline report is dependent on the individual or team retroactively reporting what they were thinking. In addition, it is also important to note that a verbal report can be achieved simply by collecting the verbal communication that occurs during an activity (assuming it is a team level activity that require communication).

Verbal reports have the potential to provide insights into team cognition during team sports. In particular, depending on the sport, communication occurs during the game. This is often communication that helps the team coordinate themselves in a meaningful way or to run a specific play. This communication is a direct link to specific cognition occurring at both the individual and team level. In addition, other ideas for using verbal reports in the sports context are to use offline reports where individuals are asked to conduct a think aloud while watching the actual game they played in. Similarly, the entire team could produce a verbal report while watching the game together.

4.3 Conceptual Techniques

Conceptual techniques are a means to elicit conceptual knowledge or cognition and explain the relationships and hierarchies among the concepts. Much like the previously highlighted families, there are many specific methods that fall within conceptual techniques (for full review see, [4]). In this paper, we choose to focus on one of the most widely used methods, concept mapping. Concept mapping is a research methodology that requires individuals and teams to specify concepts and relationships of cognitive content and structure [25]. A concept map may be an open ended activity where the participant(s) are given a focus question and asked to concept map based on the question, or the researcher can interview the participant(s) and help them produce a map. The power of concept maps for articulating team cognition is that they can be developed both individually and at a team level, and represent a direct link to cognition. In the sports context, concept maps can be applied either before or after the game at both an individual and team level.

It is apparent that all three knowledge elicitation families have a place in articulating team cognition during team sports. Yet, it is also apparent that not every method is a perfect fit for capturing cognitive processing in real time at the team level. The next two sections outline the challenges of using knowledge elicitation in sport and how to innovatively create new methods to study team sports via measuring team level cognitive processing in real time.

5 Challenges of Using Knowledge Elicitation in Sport

Traditional knowledge elicitation techniques can certainly be applied to individuals on sports teams. Knowledge of the rules of the game, the requirements of one's own position, and the capabilities and limitations of teammates or those on the opposing teams is clearly critical for effective performance. The degree to which such knowledge is shared can also be assessed and is most likely also important. However, for other action-oriented teams it has been found that knowledge and its distribution or overlap among team members, though important, is not what distinguishes effective teams from ineffective teams [2]. Rather it is the interaction among the teammates reflected in coordination dynamics and communication behaviors or cognitive processing at the team level that is central to team effectiveness. How can this kind of team expertise be elicited?

Much of the research on team interaction and its analysis has taken place in the context of military command-and control teams, such as teams who operate uninhabited aerial vehicles from the ground [2]. Parallels have been drawn between military command-and-control teams and sports teams [26], however there are also differences particularly in regard to the details of interaction. In military action-oriented teams the team-level cognitive processing happens through communication—much of it explicit. Various aspects of communication have been recorded and analyzed that include frequency, number of words, vocal tone, flow dynamics, and content [27]. This information provides a descriptive look at the team interactions or team cognition, however, it does not reveal the underlying perceptual and cognitive processes of individuals that are associated with team-level cognition and that may be useful in training individuals for teamwork. Further, extending this interaction-based approach to sports teams raises several challenges.

In contrast to military command-and-control, in which the interaction is primarily through verbal communication, team sport involves fast-paced physical interaction. Team cognition in sports can be observed less through explicit verbal communication and more so through the physical interaction among teammates. Verbal communication that does occur is often quite limited in sports (e.g., a player's name is called) or purposefully terse and obscure (e.g., the name of a play). Nonverbal communication is more common and may be as subtle as making eye contact or pointing. The challenge is to measure interaction that occurs in this manner and to be able to do so unobtrusively. Collecting data on player positioning through GPS has been used in this regard and can provide an indication of interaction patterns [28], however, as previously mentioned, this information is devoid of individual teammate "knowledge" that generated the pattern.

There are also other differences between sports teams and the traditional action-oriented teams that have been studied in the literature and that make knowledge elicitation challenging. Sports teams tend to be larger than the teams of 3–5 individuals that have been studied in the literature. In fact, sports teams may be multiteam systems [29] in the sense that the larger team can be divided in sub-teams (e.g., defense, offense). In addition, the team should probably include the coach. There are other individuals involved that may also impact the team and they include the fans and referees. Most importantly, the opposing team needs to be considered as well, as it is the primary environmental trigger for a team's actions. In understanding team cognition, these other teams and individuals are important parts of the context and need to be considered.

In sum, the assessment of team cognition in sports raises several challenges due to the focus on physical interaction as opposed to verbal interaction and due to the unclear bounds of those on the team. Team cognition in sports teams can be understood at one level through the analysis of the physical interactions of teammates. The physical interaction patterns that can be observed reflect changing dynamics of a team that indicate adaptation to the environment and resilience. However, these patterns alone are not instructive for training individual team members in that they do not provide an indication of the individual cognition that helps to generate these patterns. Some traditional knowledge elicitation methods can loosely be used for this, but new context specific methods are needed for eliciting this kind of knowledge from teammates.

6 New Methods of Knowledge Elicitation for Sport

Studying team cognition from an ecological approach will require the development of new methods of investigating the “knowledge” shared by teammates. Traditional methods of knowledge elicitation, which typically involve conscious, passive responses recorded out of context, will not be fully effective in capturing the shared coordination and communication between teammates which, according to the ecological approach, emerges during actual play and is more implicit. At the same time, research which focuses only on the macro level behavior of teammates (e.g., the movements of players from GPS data) does little to elucidate the underlying perceptual-cognitive processes. We next consider some possible paradigms that could represent a middle ground between purely passive knowledge elicitation methods and macro level measures of team performance outcomes.

A fruitful approach for studying team cognition in sport may be to “scale up” paradigms that have been shown to be highly effective for assessing cognition at the individual athlete level. For example, the temporal occlusion paradigm [30]. This method involves a participant viewing an unfolding action (e.g., a tennis serve) either on video or live. At a designated point in time (e.g., 150 ms before racquet-ball contact) that participant’s view is occluded (e.g., by freezing the video or with occlusion glasses). The participant is then required to anticipate the outcome of the action (e.g., cross court or down-the-line severe) either with a verbal response or initiating a movement in reaction. For one-on-one actions in sports (e.g., returning a serve, hitting a baseball or stopping a penalty kick in soccer), this method has consistently demonstrated that skilled athletes are more accurate at anticipating the outcome and can do it successfully at earlier occlusion points as compared to less skilled athletes [31]. This expertise difference occurs because skilled performer are better at picking up the advance cues (e.g., the movement kinematics or body language) of their opponent [31].

The temporal occlusion paradigm has also been applied to sporting actions involving multiple players in team sports. In these studies, the participant is again shown an unfolding action (e.g., the movement of players on a basketball court) that is occluded at some point. They are then asked to make a decision about what action they would perform next (e.g., dribble the ball to the net, pass to teammate X or pass to teammate Y). Coaches' assessments of the videos are then used to assess the appropriateness of the participant's decision. Research using this paradigm has again showed that skilled athletes are make more appropriate and faster decisions as compared to less skilled player (e.g., [32]). For the both the anticipation and decision making paradigms it has also been shown using eye tracker data that expert athletes have different gaze behavior than lesser skilled ones. In particular, they tend to fixate longer on a small number of key areas (e.g., [33]).

An interesting extension of these paradigms could involve multiple participants from the same team making coincident decisions or anticipation judgments. For example, a video of an unfolding basketball play could be filmed using mobile cameras attached to three different players on the team (e.g., point guard with ball, shooting guard and forward). These videos could then be shown to three participants who are each asked to make a decision at the same occlusion point. The agreement between their responses could then be used as an index of team coordination. Alternatively, the same unfolding play could be filmed from the perspective of three players on the defending and then used to create a task which involves anticipating the action of the player with the ball. By adding eye tracker it would also be possible to determine the relationship between the visual search behavior of teammates. Do athletes that have a lot of experience playing look at the same areas on their opponent's body? Do they look towards the same openings on the court? By measuring the agreement between player's decision it would also overcome a short coming in sport decision making research that "good" decision are determined by assessments of what "should be done" by a group of coaches, a practice which penalizes any type of unexpected play or creativity.

Another area that is need methodological development in team cognition in sports research is nonverbal communication. Previous research has shown that athletes communicates in many difference ways including using gestures, gaze direction, movement, body orientation and touch [34]. For example, in netball, verbal directives given by teammates are accompanied by gestures 12.5 % of the time and failures in taking into account the different orientation of a teammate when making a gesture accounts for a high proportion of communication problems [34]. In basketball, it has been shown that the rate at which NBA teammates touch each other during play is directly related to their level of cooperation and on-court performance [35]. Although these studies have produced some interesting findings, they rely on remote videos which are labor intensive to code and are likely to miss many subtle forms of communication. Furthermore, previous research of this type has been mostly descriptive. While there have been some initial attempts to model non-verbal communication flow in sports (e.g., [36, 37]) it will be important to develop more detailed models of communication flow as has been done for verbal communication in other domains [2].

7 Concluding Thoughts

Team cognition is beginning to be realized as an important facet of team sports. As we continue to articulate the role of team cognition during team sports, we need to understand how to measure team cognition. In this paper, we presented multiple knowledge elicitation methods to measure team cognition, while also proposing new elicitation methods that account for the dynamic nature of team sports.

References

1. McNeese, N., Cooke, N., Fedele, M., Gray, R.: Theoretical and methodical approaches to studying team cognition in sports. In: 6th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences. Applied Human Factors & Ergonomics, pp. 1211–1218. Las Vegas, Nevada (2015)
2. Cooke, N.J., Gorman, J.C., Myers, C.W., Duran, J.L.: Interactive team cognition. Cogn. Sci. **37**, 255–285 (2013)
3. Salas, E., Cooke, N.J., Rosen, M.A.: On teams, teamwork, and team performance: discoveries and developments. Human Factors J. Human Factors Ergon. Soc. **50**(3), 540–541 (2008)
4. Cooke, N.J.: Varieties of knowledge elicitation techniques. Int. J. Human-Comput. Stud. **41** (6), 801–849 (1994) (Elsevier)
5. Rybing, J., Nilsson, H., Jonson, C., Bang, M.: Studying distributed cognition of simulation-based team training with DiCoT. Ergonomics 1–38 (2015)
6. Cuevas, H.M., Fiore, S.M., Caldwell, B.S., Strater, L.: Augmenting team cognition in human-automation teams performing in complex operational environments. Aviat. Space Environ. Med. **78**(5), B63–B70 (2007)
7. Andres, H.P.: Team cognition using collaborative technology: a behavioral analysis. J. Manag. Psychol. **28**(1) (2013)
8. Cannon-Bowers, J.A., Salas, E., Converse, S.: Shared mental models in expert team decision making. In: Castellan Jr., N.J. (ed.) Individual and Group Decision Making: Current Issues, pp. 221–245. Erlbaum, New Jersey (1993)
9. Klimoski, R., Mohammed, S.: Team mental model: construct or metaphor? J. Manag. **20**(2), 403–437 (1994). doi:10.1016/0149-2063(94)90021-3
10. Mohammed, S., Dumville, B.C.: Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. J. Organ. Behav. **22**, 89–106 (2001)
11. Mathieu, J.E., Goodwin, G.F., Heffner, T.S., Salas, E., Cannon-Bowers, J.A.: The influence of shared mental models on team process and performance. J. Appl. Psychol. **85**(2), 273–283 (2000). doi:10.1037/0021-9010.85.2.273
12. Van den Bossche, P., Gijselaers, W., Segers, M., Woltjer, G., Kirschner, P.: Team learning: building shared mental models. Instr. Sci. **39**(3), 283–301 (2011). doi:10.1007/s11251-010-9128-3
13. Reimer, T., Park, E.S., Hinsz, V.B.: Shared and coordinated cognition in competitive and dynamic task environments: An information-processing perspective for team sports. Int. J. Sport Exerc. Psychol. **4**, 376–400 (2006)
14. Eccles, D.W., Tenenbaum, G.: A social-cognitive perspective on team functioning in sport. In: Tenenbaum, G., Eklund, R. (eds.) Handbook of Sport Psychology (3rd edn.), pp. 264–283. Wiley, New York (2007)

15. Giske, R., Rodahl, S.E., Høigaard, R.: Shared mental task models in elite ice hockey and handball teams: does it exist and how does the coach intervene to make an impact? J. Appl. Sport Psychol. **27**(1), 20–34 (2015)
16. Bourbousson, J., Poizat, G., Saury, J., Sève, C.: Temporal aspects of team cognition: a case study on concerns sharing within basketball. J. Appl. Sport Psychol. **24**(2), 224–241 (2012). doi:10.1080/10413200.2011.630059
17. Cooke, N.: Team cognition as interaction. Curr. Dir. Psychol. Sci. **24**(6), 415–419 (2015)
18. Chemero, A., Ebrary, I.: Radical embodied cognitive science. MIT Press, Cambridge, MA (2009)
19. Nardi, B.: Context and consciousness: activity theory and human-computer interaction. MIT Press, Cambridge, MA (1996)
20. Silva, P., Garganta, J., Araújo, D., Davids, K., Aguiar, P.: Shared knowledge or shared affordances? insights from an ecological dynamics approach to team coordination in sports. Sports Med. **43**(9), 765–772 (2013)
21. Mohammed, S., Ferzandi, L., Hamilton, K.: Metaphor no more: a 15-year review of the team mental model construct. J. Manag. (2010)
22. McNeese, N., Reddy, M., Friedenberg, E.: Team mental models within collaborative information seeking. In: 2014 Annual Meeting of the Human Factors and Ergonomic Society, pp. 335–339. Human Factors and Ergonomics Society, Chicago, IL (2014)
23. McNeese, N., Reddy, M.: Articulating and understanding the development of a team mental model in a distributed medium. In: 2015 Annual Meeting of Human Factors and Ergonomic Society, pp. 240–244. Human Factors and Ergonomics Society, Los Angeles, CA (2015)
24. Cooke, N.J., Salas, E., Cannon-Bowers, J.A., Stout, R.J.: Measuring team knowledge. Human Factors J. Human Factors Ergon. Soc. **42**(1), 151–173 (2000)
25. Novak, J.D., Cañas, A.J.: The theory underlying concept maps and how to construct them. Florida Institute for Human and Machine Cognition (2006)
26. Pedersen, H.K., Cooke, N.J.: From battle plans to football plays: extending military team cognition to football. Int. J. Sport Exerc. Psychol. **4**, 422–446 (2006)
27. Cooke, N.J., Gorman, J.C.: Interaction-based measures of cognitive systems. J. Cogn. Eng. Decis. Making Spec. Sect. Integrating Cogn. Eng. Syst. Eng. Process Opportunities Challenges Emerg. Approaches **3**, 27–46 (2009)
28. Araujo, D., Silva, P., Davids, K.: Capturing group tactical behaviors in expert team players. In: Baker, J., Farrow, D. (ed.) (2015). Routledge Handbook of Sport Expertise, pp. 209–220. (2014)
29. DeChurch, L.A., Marks, M.A.: Leadership in multiteam systems. J. Appl. Psychol. **91**, 311–329 (2006)
30. Abernethy, B., Russell, D.G.: Advance cue utilization by skilled cricket batsmen. Aust. J. Sci. Med. Sport **16**, 2–10 (1984)
31. Muller, S., Abernethy, B.: Expert anticipatory skill in striking sports: a review in model. Res. Q. Exerc. Sport **83**, 175–187 (2012)
32. Martell, S.G., Vickers, J.N.: Gaze characteristics of elite and near-elite athletes in ice hockey defensive tactics. Hum. Mov. Sci. **22**, 689–712 (2012)
33. Savelsbergh, G., Williams, A.M., Van der Kamp, J., Ward, P.: Visual search, anticipation and expertise in soccer goalkeepers. J. Sports Sci. **20**, 279–287 (2002)
34. LeCouteur, A., Feo, R.: Real-time communication during play: analysis of team-mates' talk and interaction. Psychol. Sport Exerc. **12**, 124–134 (2011)
35. Kraus, M.W., Huang, C., Keltner, D.: Tactile communication, cooperation, and performance: an ethological study of the NBA. Emotion **10**, 745–749 (2010)
36. Lausic, D., Tenenbaum, G., Eccles, D., Jeong, A., Johnson, T.: Intrateam communication and performance in doubles tennis. Res. Q. Exerc. Sport **80**, 281–290 (2009)
37. Zourbanos, N., Tzioumakis, Y., Araújo, D., Kalaroglou, S., Hatzigeorgiadis, A., Papaioannou, A., Theodorakis, Y.: The intricacies of verbalizations, gestures, and game outcome using sequential analysis. Psychol. Sport Exerc. **18**, 32–41 (2015)

A Naturalistic Neurophysiological Assessment of Photographer Cognitive State in the Vicinity of Mount Everest

John G. Blitch

Abstract A number of cognitive studies support the notion that task focus and mental workload fluctuation in human perceptual activities can be modeled on a dynamic basis in near real time. Few of these studies, however, involve the use of wearable technologies in naturalistic settings. Fewer still do so under conditions of high physiological stress like those encountered on steep slopes at high altitude in foreign environments. This study compares the behavior and cognitive state of photographers climbing to and descending from the vicinity of Everest Base Camp at altitudes approaching 18,000 feet. Ascent and descent activities were compared in terms of overall task engagement, cognitive workload, and behavioral components of the point and shoot decision paradigm involved in adventure photography. Results are discussed in the context of decision-making behavior typically associated with wilderness search and rescue activities carried out at high altitude in environmentally challenging environments.

Keywords Cognitive state · Mental engagement · Workload · Decision-Making · Search and rescue

1 Introduction

There is an old adage in the U.S. Army Ranger handbook that calls for dismounted patrols to avoid returning from an objective by the same route that was used on approach—ostensibly to avoid ambush by enemy forces who may be engaged in tracking activities [1]. There may however, be another more cognitively evolved rationale for this time-tested tactic. It has been established in a number of laboratory experiments that a nearly insatiable penchant for pattern matching makes human beings particularly vulnerable to complacency effects in the form of vigilance decrement [2] and disengagement even in dynamic and demanding tasks like air

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traffic control [3] and semi-autonomous robot supervision [4, 5] where the onset of mere boredom seems to be out of the question. In any case, a reconnaissance patrol that becomes complacent and misses critical environmental cues while on the move will inevitably fail in their mission regardless of whether they ever get ambushed—especially when search and rescue activities are involved. Nothing is more devastating for soldier or adventure athlete, after all, that to leave a comrade behind in the face of danger.

The current study endeavored to examine the issue of complacency in a natural, operationally relevant setting beyond the highly structured laboratory environment where risk and environmental conditions are rigorously controlled in pursuit of crisp quantitative cause-effect correlations. Unfortunately, such correlations can come at a cost in ecological validity by those wishing to extend their findings into the unstructured "real" world. By exploiting recent progress in wearable computing, neurophysiological (brainwave) data was collected on a group of adventure photographers attempting to capture the stunning, awe-inspiring landscape surrounding Mt. Everest and its neighboring peaks in Nepal's Sagarmatha National Park. This data was used to compare the cognitive state of participant photographers during ascent and descent phases of their activity in order to examine which phase might be more inclined to produce complacency effects.

It is important to note that subjective measures of mental workload, situational awareness, and other aspects of cognitive state that are commonly used elsewhere in human factors research were rejected for this project for a number of reasons, but primarily due to their potentially intrusive nature as described by Parasuraman, Wilson and others [6, 7]. Not only does the injection of Question and Answer (Q&A) protocols into field activities potentially interfere with the task at hand, they may actually disrupt the intuitive and imaginative processes underlying creative and artistic activities such as photographic scene selection.

In any case, the primary hypothesis examined in this study (hereafter referred to as the Ranger hypothesis) predicts that participants returning along the same route used during ascent will show evidence of increased complacency during descent as indicated by EEG indices of brain state and task related behavior (i.e., missing photo-worthy cues). An alternative hypothesis suggests that photographers might actually be less complacent and more active on descent, due to reduced physical exertion and the joyful, positive affect of returning to a more hospitable environment somewhere down the trail.

2 Method

2.1 Apparatus

This experiment was conducted with three primary pieces of equipment: a hand held cell phone camera (Casio C771 Commando with a 5 megapixel camera and

Fig. 1 B-Alert wireless EEG system worn under participants' headgear

480 × 800 pixel display), a Panasonic Toughbook laptop (CF-19 with a standard voltage Intel Core i5 vPro processor) and a wireless EEG (Electro Encephalo Graphy) monitoring device called the X-10 B-Alert system manufactured by Advanced Brain Monitoring of Carlsbad CA. This last device acquires 9 channels of EEG collected across the scalp and mastoid leads along with ECG from the clavicle and sternum. The sensor locations for this system comprise: Fz, Cz, POz, F3, F4, C3, C4, P3, and P4. Data are sampled at 256 Hz with a band pass from 0.5 to 65 Hz (at 3 dB attenuation) obtained digitally with Sigma-Delta A/D converters. The RF link is frequency-modulated to transmit at a rate of 57 kBaud in the 915 MHz ISM band. By utilizing a bidirectional mode, the firmware allows the host computer to initiate impedance monitoring of the electrodes, select the transmission channel (so two or more headsets can be used in the same room), and monitor battery power of the headset. Data are acquired across the RF link on a host computer via an RS232 interface. Signal acquisition software then stores the EEG data on the host computer. The proprietary acquisition software used in this process includes artifact decontamination algorithms for eye blink, muscle movement, and environmental/electrical interference such as spikes and saturations.

One important aspect of this device is that the wireless nature of its hardware all but eliminates participants' awareness of its presence within just a few minutes of wear. It is lightweight and compact enough to fit comfortably under a climber's headgear (as indicated in Fig. 1). As such, this system presents a significant contrast to high-density EEG systems common to laboratories and hospitals that are cable intensive and typically require electrodes to be placed on the face and other highly sensitive regions which remain prominent in the perceptual realm of the user.

2.2 Participants

Four photographers from the 2014 Himalayan Workshops expedition to Mount Everest basecamp volunteered to participate in this experiment at a monetary incentive rate of $10 (US) per hour for a maximum of 4 hours. All four participants were experienced photographers with an extensive history of international travel. Two were citizens of Germany, and two others were from Sweden and the United States respectively.

2.3 Design and Procedure

Baseline profiles of cognitive state and workload were collected for each participant under nominal (hotel room) conditions. These profiles captured each participant's EEG pattern during the performance of three baseline tasks.

The first baseline task required the participant to remain vigilant while choosing between different symbols presented on a laptop display. The EEG collected during this task is modeled as a state of Hi Engagement that is typical of decision-making activity. This data also contributes to the classification of cognitive workload discussed below. The second task required a simple keyed response to a single stimulus (a red circle appearing on the screen) without any choice or decision-making process involved. The EEG profile established during this task corresponds to a state of Lo Engagement or awareness. The third task requires the participant to respond in a similar fashion to the second task, but with an auditory stimulus presented while their eyes were closed. Data collected during this final task is modeled in conjunction with a large database of typical human sleep profiles to establish states of drowsiness and distraction respectively. The baseline EEG collected during these three tasks is subsequently compared with data collected in the field environment while participants performed "mission" tasks of interest—in this case selecting a photo worthy scene and taking any number of pictures to capture its essence.

Field data was collected on the ascent and descent phases of each participant's approach to Mt. Everest. Although several portions of the ascent and descent routes varied, data was only collected on participants where ascent and descent routes overlapped along the same trail section. It should be noted that weather effects were nearly identical for both the ascent and descent phases for all participants. Bright sunshine dominated throughout the day with only 20–30 % cloud cover. Temperatures ranged between 45–65 °F without any precipitation observed during data collection periods.

2.4 Measures

By comparing EEG collected in the field to the data collected under nominal baseline conditions, the system's proprietary software classified the cognitive state of each participant in terms of their relative task engagement, drowsiness, and mental workload. These data were presented in terms of probability components indicating that the participant was either drowsy (a combination of EEG characteristics indicating distraction and sleep onset), task-engaged at a low (non-choice) level, or task-engaged at a high (choice/decision required) level. These probabilities were all components of engagement and thus added up to a total of 1.000. A separate probability for Hi Workload demand was calculated by the software based on each participant's performance in the choice-required baseline task and a historical data base of EEG collected on thousands of participants during representative performance on forward and backward span tasks. See Berka et al. 2004 for more detail on this classification process [8].

Behavioral indicators of complacency were recorded by a hand held cell phone camera and tabulated in terms of photo stops (as opposed to rest stops due to physical exertion) and number of pictures taken. The correlation between both of these metrics and the Ranger hypothesis was assumed to be positive. In other words, a reduced number of stops and fewer pictures taken would suggest a reduction in task focus and complacency onset.

3 Results

Given that data was collected on the same participants across two temporal phases, initial analysis was performed using a paired t-test with a relaxed alpha set at 0.10 to accommodate the inherent variance involved with data collected in dynamic unstructured environments. The EEG data illustrated in Fig. 2 indicate a prominent trend toward decreased engagement, reduced workload, and more drowsiness during descent.

Considering the "Lo" or awareness based metric first, participants recorded a significantly higher probability of engagement on average during the ascent phase ($M = 0.260$, $SD = 0.191$) than the descent phase ($M = 0.178$, $SD = 0.185$), $t(3) = 1.884$, $p < 0.10$ with a relatively large effect size (Cohen's $d = 0.46$). Regarding the "Hi" or vigilant choice metric, participants also recorded a higher probability of engagement during ascent ($M = 0.469$, $SD = 0.320$) than descent ($M = 0.350$, $SD = 0.189$), but at a level that fell short of statistical significance $t(3) = 0.833$, $p > 0.10$. The third engagement metric indicated a higher probability of drowsiness during descent ($M = 0.436$, $SD = 0.219$) than ascent ($M = 0.269$, $SD = 0.183$), but at a statistically insignificant level $t(3) = 1.237$, $p > 0.10$.

The probability of high workload classification associated with ABM's backward/forward span task database demands that it be evaluated separately from

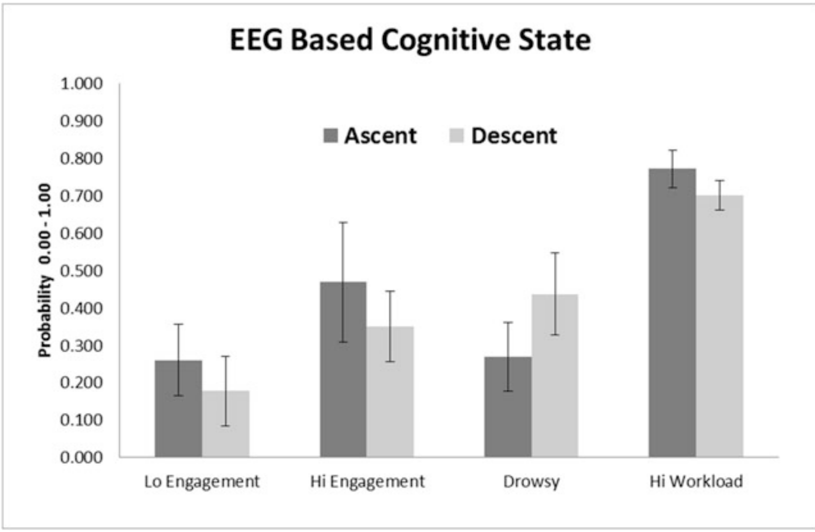

Fig. 2 EEG Based cognitive state probabilities during ascent and descent (with standard *error bars*)

the engagement data. With that in mind, it was observed that participants were far more likely to be operating under a Hi Workload profile during the ascent phase (M = 0.771, SD = 0.099), than during the descent phase (M = 0.699, SD = 0.079), but at a statistically insignificant level $t(3) = 1.104$, $p > 0.10$.

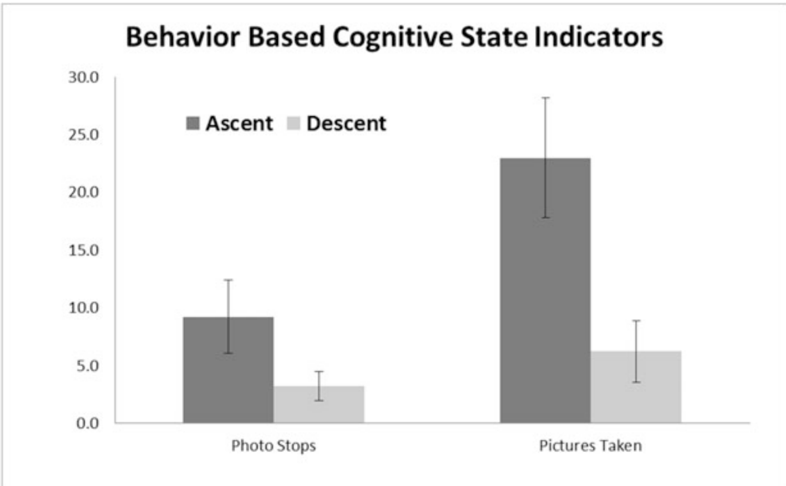

Fig. 3 Estimated number of photo stops and pictures taken (with standard *error bars*)

Behavioral data was estimated after the fact by video review of each participant's ascent and descent activity captured by hand held cell phone camera, and is presented in Fig. 3. The estimated number of photo stops observed during the ascent phase ($M = 9.3$, $SD = 6.4$), was significantly larger than those observed during descent ($M = 3.3$, $SD = 2.5$), $t(3) = 2.70$, $p < 0.05$, Cohen's $d = 1.1$. The estimated number of pictures taken was also substantially larger during ascent ($M = 23.0$, $SD = 10.4$), than during descent ($M = 6.4$, $SD = 5.3$), $t(3) = 5.04$, $p < 0.01$, Cohen's $d = 1.42$.

4 Discussion

The EEG data presented above are insufficient on their own to make a case for the Ranger hypothesis, especially in light of a relaxed alpha and recognized lack of correction for familywise error. Despite this increased likelihood of Type I error, however, the relatively large effect size associated with the Lo Engagement metric, combined with the strong evidence provided by behavioral data, present a reasonable expectation that these results would be replicated in a manner consistent with Wickens' common sense statistics [9]. This assumes, however, that a larger number of participants willing to endure the hardships associated with this challenging endeavor can be identified and taken through the informed consent process.

It is important to note that while EEG based classification of cognitive state and workload was conducted on a post hoc basis for this investigation, the B-Alert system has the ability to conduct these classifications on the fly in near real time (with display delays running from 1–5 s depending on signal characteristics and features chosen). As such it is a relatively simple process for a patrol leader to monitor the cognitive state of team members wearing the device and observe significant changes within just a few seconds of their occurrence. This data has the potential to detect a task engagement lapse or other complacency issue *before* it actually manifests as an appreciable decline in performance.

5 Conclusion and Future Work

In conclusion, this initial investigation establishes ample evidence of complacency onset during the descent phase of dismounted patrols returning along the same route as their ascent. It is recognized that operational risks (avalanche danger, enemy observation, inclement weather, etc.) may preclude alternate route selection during descent, so leadership may have to invoke other mitigation strategies such as rotating the personnel on point more often or increasing compass/pace checks. Future work should focus on first validating the findings stated above with a substantially increased number of participants, and then exploring which mitigation strategies show the greatest potential in terms of cognitive state observations and complacency indicators. Subjective measurement methods should also be invoked as well, assuming that an experimental design which more closely emulates a search and rescue paradigm can be established without the concern for disruption of creative or artistic flow.

It is important to note that the potential for confounding variables to threaten naturalistic research of this nature is high. Fatigue, emotional valence, social interaction and a number of other factors undoubtedly contributed to the relatively large variance of data presented here. It is in that context that this effort presents its greatest value—in the promotion ecological validity for those performing difficult tasks in dynamic, unstructured, and risk intensive environments. Conducting human factors research under such conditions presents a wide variety of daunting challenges to overcome—not the least of which is finding a sufficient number of participants and experimenters to accept risk and endure hardship while conducting complicated research in the first place. It is only with continued vigor in pushing beyond the walls of the laboratory into the "real" world, however, that we can truly come to understand the most complicated and adaptive aspects of human cognition.

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References

1. US ARMY, Ranger Handbook. Ranger Training Brigade, USA Fort Benning GA (2004)
2. Finomore, V., et al.: Predicting vigilance: a fresh look at an old problem. Ergonomics **52**(7), 791–808 (2009)
3. Kaber, D.B., Endsley, M.R.: The effects of level of automation and adaptive automation on human performance, situation awareness and workload in a dynamic control task. Theor. Issues Ergon. Sci. **5**(2), 113–153 (2004)
4. Parasuraman, R., Manzey, D.H.: Complacency and bias in human use of automation: an attentional integration. Hum. Factors **52**(3), 381–410 (2010)
5. Parasuraman, R., Wickens, C.D.: Humans: still vital after all these years of automation. Hum. Factors **50**(3), 511–520 (2008)
6. Parasuraman, R., Wilson, G.F.: Putting the brain to work: neuroergonomics past, present, and future (cover story). Hum. Factors **50**(3), 468–474 (2008)
7. Wilson, G.F., Russell, C.A.: Psychophysiologically determined classification of cognitive activity in human factors and ergonomics society 48th annual meeting. HFES. 95–98 (2004)
8. Berka, C., et al.: Real-time analysis of EEG indexes of alertness, cognition, and memory acquired with a wireless EEG headset. Int. J. Human-Comput. Interac. **17**(2), 151–170 (2004)
9. Wickens, C.D.: Commonsense Statistics. Ergon. Des. Quart. Human Factors Appl. **6**(4), 18–22 (1998)

Cognitive and Application Barriers to the Use of "Agonology in Preventive and Therapeutic Dimension"

Roman Maciej Kalina

Abstract The term "*agonology in preventive and therapeutic dimension*" is an abbreviation informating for application of science about struggle (*agonology*) in preventive and therapeutic *dimension*. Its rational use is limited by widespread lack of knowledge about this science. Preventive and therapeutic value of *agonology* primarily relates to i.a. to micro scale (an individual or a small group). This formula of *agonology* is typically applied in upper-medium scale to the victory of Mahatma Gandhi over the British Empire who masterfully used the *non-violence* (method to struggle without violence). It does not matter that the term "*agonology in preventive and therapeutic dimension*" historically emerged later than *non-violence*. *Agonology* is an interdisciplinary science which is still evolving and since 1991 its *preventive and therapeutic* dimension has been developing. *Agonology* analyses the effectiveness of methods incorporated into a defensive fight and formulates practical rules which do not tolerate any form of retaliation for physical or verbal aggression, or combination thereof that goes beyond necessary counteractive methods and measures which fall within the criteria of self-defence. As the most effective counteractive measure of even the most violent verbal aggression, *agonology in preventive and therapeutic dimension* recommends the method established by Buddha Sakyamuni. If it is assumed that peace is the greatest global welfare, then armed fights (wherever they take place) based on mutual destruction would inevitably lead to total destruction. This is just a matter of time. If it is believed that science is the second greatest global welfare, ignoring the *preventive and therapeutic* features of *agonology* will only accelerate this process.

Keywords Agonology · Sports science · Sports medicine

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1 Introduction

Development of "*agonology in preventive and therapeutic dimension*" is both a necessity and a chance for global civilisation. *Agonology* is a science about struggle established—under this name—by Kotarbiński [1]. Its rational use is limited by widespread lack of knowledge about this science [2–4]. Since 1991, I have been developing its *preventive and therapeutic dimension* [5]. In this sense, *modern agonology* [6] is an interdisciplinary science closely related to the law and practicality, in particular to the micro scale and only seemingly of micro scale.

A flawed law used while judging perpetrators and victims of interpersonal aggression provides numerous proofs that common lack of scientific knowledge about *agonology* is a source of great freedom to manipulate the facts by both parties—the prosecution and defence. Intelligence, erudition, ability to use eristic by lawyers determine that in one case the fact of using acute measures for counteracting aggression (strikes with limbs) by a boxer, kickboxer, karateka, taekwondo athlete, etc. is considered by the court to be an acceptable manner to execute the self-defence right. In other cases—the court agrees with the argument that the long-lasting training of strikes with arms or arms and legs a maximum exposure of muscle strength cannot be considered as a mitigating factor. On the contrary—in this case, paradoxically, the perpetrator becomes the victim, as an athlete with such abilities defending oneself formally (but whether objectively?) exceeded the criteria of the self-defence right.

This paradox is perhaps the clearest example of *homo sapiens* hypocrisy: *homo agonisticus* dominates over *homo cogitans* [6, 7]. It is also the clearest evidence of the cultural and pragmatic barriers to the implementation of *agonology in preventive and therapeutic dimension* on a global scale.

The main objective of this paper is the argumentation regarding cognitive and application barriers which prevent the most protective dimension of the science about struggle—*prophylactic and therapy agonology* from being implemented in the global science and in practice. The reasoning serves at the same time as the method which is based on interdisciplinary knowledge and my theoretical research experience related to development of the science about struggle as well as empirical ones devoted to verification of the most significant hypotheses. The knowledge I have obtained during my long-lasting cooperation with professor Jarosław Rudniański cannot be overstated (the most intensive period took place in years 1988–1990 when under the direction of prof. Rudniański I participated in scientific internship in the Institute of Philosophy and Sociology of the Polish Academy of Science). This knowledge, which is still processed in my mind from the view of the facts which occurred in the last 25 years since the *Iron Curtain* has been overthrown (1989), has an intellectual potential providing me with the greatest inspirations.

2 In a Trap of the Sport Science Paradigm and the Crisis of the Olympism Ideals

Sport during the Cold War (1947–1991) was one of the major means of propaganda in political struggle (negative political cooperation). However, if the political and patriotic context with respect to all dissimilarities is left aside, the conclusion harbours no illusion. Expansion of own aggressiveness released by reprehensible social actions is justified by identifying oneself with the national team, sports club, sports star (celebrity) is ensured by establishment of the large groups of sport fans. In such a way, a unit ensures oneself a wide margin of impunity for violence and aggression.

The Soccer War [8] between Honduras and Salvador took place in 1969, even though both countries were not members of the hostile political blocs. After the football match on 15 June 1969 as part of the elimination of the FIFA World Cup 1970 (representation of El Salvador won 3–0), riots between supporters of both representations broke out and resulted in two fatalities. After this event, in Salvador mass demonstrations were organised against Honduras. Afterwards both countries broke their diplomatic relations and several hours later the border became closed. This constituted the beginning of the soccer war.

The Heysel Stadium disaster occurred on 29 May 1985 (in Brussels, Belgium). Before the European Cup Final between Juventus of Italy and Liverpool of England there was a confrontation of English and Italian fans, which resulted in death of 39 people and 600 injured ones. The riot started at approximately 7.00 p.m. Liverpool fans easily broke through the small fence and attacked the Juventus fans. Italian fans began to flee, trampling each other. Some people were crushed by a 3 m wall which collapsed under the pressure of the crowd [9].

There is no end to fights of fans and their killings, injuries, devastation of infrastructure and cars, etc. Contrary to the key principle of the Olympic Charter: fair play officially approved by athletes [10], interpersonal aggression is exhibited even by the greatest sport stars, coaches, referees and other people related to sport. In years 1995–2007, I participated several times in interventions during events such as the Military World Games and Military World Championships in Judo CISM (*Conseil International du Sport Militaire* [11]) as a member of the Jury Appeal. The prime motto of CISM “Friendship Through Sport” is in this case the sarcastic example confirming this argumentation.

Despite these objective facts, the paradigm of sport science is based on the naive assumption that sport and physical exercises are one of the most effective manners to shape health and well-being available to everyone [12–14]. In fact, this is only the alternative. Only after satisfying certain requirements, sport and physical exercises may stimulate all dimensions of health (somatic, mental and social) and prepare a human being to survive in many difficult situations on land and in water.

The mission of science and the seriousness of scholar's status oblige us to the truth. Thus, this paradigm of sport science will not compromise the science as a whole. The last two sentences will become clearly understood if we assume the criteria of reism and replace word "science" with the term "people of science" (in more general arguments it is more convenient to use the word "science"). Numerous published scientific and popular science manuscripts prove that institutional science, as many other areas of life, is prone to the effects of the so-called authorities, fashion and primarily media who apart from implementation of their own goals also represent the interests of different groups related to politics, business, etc., including those related to sport and Olympic movement.

The crisis of Olympic mission (the spirit, principles, and ideals of modern Olympic Games), which in global social dimension means: commitment to or promotion of these values approaches the critical point. Will it become a turning point in negative or positive sense?

This is an open question, from which science cannot distance itself. The bane of doping and short-term disqualifications against the Olympism values (except for a few life-long cassations of titles and records after long-lasting investigations and litigation), corruption, fraud, violence, etc. will sooner or later result in a revolutionary paradigm shift in sports science. If the principle: *nemo iudex in causa sua* or *nemo judex in sua causa* ("no-one should be a judge in his own cause") is binding in the natural justice, there is—*per analogiam*—a dilemma emerging: according to which science should the paradigm of sport science be criticised?

The association with the philosophy of science comes into the mind along with fear of justified reasoning that philosophy is not a science although it unquestionably remains in close relation with it [15–19]. Due to the broad context of social and legal consequences arising out of cumulated negative phenomena in sport and Olympic movement, this issue requires a multi-disciplinary analysis. This is even more difficult as the applications cannot be reduced only to science or philosophy. They must be reflected in political decisions, which will result in certain international consequences, and in law applied in every civilised and democratic country.

Although sport science is a good example of interdisciplinarity, the rational criticism may be based on praxeology (science about good work) and ethics. Being similar to agonology, praxeology, also referred to by Tadeusz Kotarbiński as general methodology [20], is unfortunately limited by widespread lack of knowledge about this science. This however is not a fundamental obstacle. As the precise language of praxeology is suitable for considerations involving many disciplines of science, it is important that a critic of sport science paradigm would be able to use it proficiently enough so that the explanatory hypotheses, conclusions and recommendations will be approved in science and social practice. The role of ethics does not require any additional explanations. This is a canon present both in science and Olympism. Unfortunately, violation of elementary ethical norms is the cause of crisis in these disciplines [4].

3 Maximisation of Activities in Sport—The Most Problematic Justification for Sport Science and Sport Medicine

The essence of every detailed science is to justify its assertions. As applied sciences, sport science and sport medicine are related with practical sphere of broadly understood sport. In this practice, institutional solutions are still based on the following mottos: *mens sana in corpore sano*, *Citius—Altius—Fortius*, "sport equals health", etc., although examples and current media news about pathology in sport referred to in the second chapter clearly contradict their compliance with reality [21].

The psychological concept of *catharsis* failed to reduce human aggressiveness [22, 23]. It should be expected that due to science the Olympic motto: *Citius—Altius—Fortius* (Olympic chapter "Knowledge Elicitation Methods for Developing Insights into Team Cognition during Team Sports", The Olympic Movement, point 10 [10]) will not withstand criticism and sooner or later modern Olympism will be revised. Hopefully, it will happen before global society disguised of growing social inequalities, corruption along with expenditures on the infrastructure of further Olympic Games and the range of pathology in sport itself will result in the same act as of Theodosius I the Great did in 393—namely, he abolished the Ancient Olympic Games.

Leaving aside the issue of reprehensible verbalization and presentation of sports events by the media in a manner inconsistent with the spirit of Olympism, I would like to emphasise on common approval of disastrous sport doctrine "to push the boundaries of human capabilities"—to achieve record results and win at all costs (i.e., with no regard for health while maintaining the semblance that the fair play rule is respected). This doctrine enforces the maximisation of actions in sport, also for children and youth, and gave birth to professional sports, which captured the Olympic Movement.

The maximisation may be broadly understood. It is obvious that not every sport involves extreme energy expenditure. The programme of summer Olympic Games comprises 36 sports disciplines and 302 competitions in which sets of medals are awarded afterwards. The energy factor (*citius, altius, fortius*) prevails only in 54 % of all competitions. Shooting sports (15 competitions) is a sport in which this factors is extremely reduced, but maximisation is visible in the need to very precisely repeat handling of a specialist tool (a firearm). In archery competitions, motor activity of an athlete is related to a certain form of exposure of muscle strength, combined with the need to precisely use older type of weapon, i.e., an arc. The factor involving maximisation of effort and precise actions is a domain of team sports and racket sports. Combat sports athletes are most affected by the effects of maximisation of actions, because permitted forms of physical pressure are directed towards competitor's body. The claim that fencers are in a comfortable situation is illusionary. In February 2009, during the training a 17 year-old fencer from AZS AWF Warszawa (Poland) impaled himself on the opponent's foil. He was transferred to the hospital, but he did not survive—this is not an isolated example in the history of fencing.

In the programme of winter Olympic Games, the energy factor prevails among 15 sports disciplines and 98 competitions and furthermore each sport without exception involves using certain equipment (skates, skis, sledges, etc.).

The common feature shared by every sport involves offensiveness from which there is—to use customary phraseology—one step from aggression, especially in combat sports, team sports and tennis. Furthermore, if combat sports athletes are not eager to attack, they are subject to penalties, which may even include disqualification. If in a limited time basketball or handball team does not throw the ball into the basket (handball gate), it has to be passed to the opponent. These are details which are only seemingly insignificant. Ultimately, only one athlete or team may win. The others lose. Along with professionalization of sport which translates into fame and fortune of the winners, there is a great temptation to break the rule. Details from the regulations become important, thus it is not surprising that language and practice of the most significant entities in sport (coaches, competitors, commentators, fans) commonly involves the notion of "aggressive defence". Referees are subject to this pressure, thereby making sports events more dramatic but further from health-related and humanistic mission of sport.

The scholars who represent sport science and sport medicine essentially limit themselves to the reports which document cases involving fatalities and injuries related to sports activity and on the other hand aggression, doping and other pathologies. Finally, there are also recommendations which are mostly ignored by coaches, athletes and sports organizers of the different levels.

There is numerous empirical evidence. The most recent studies confirm that many athletes continued to train or even participated in competitions without uncured sports injury or overload [24, 25]. Data about fatalities and injuries in judo are documented, even though safe fall is permanently trained in this sport. This does not result in the radical change of the regulations, principles of training and selection to professional sport [26, 27]. Similarly, knowledge about extremity injuries sustained by falling during snowboarding [28] did not revolutionised methodology of this sport on its initial stage.

What is left is a criticism of mainly false hypothesis about utilitarian value of sport, in particular addressed to soldiers, police officers and all security formations. In the era of intensified terrorism, this issue is of particular importance.

Among various sports it is biathlon which draws attention. It is based on seemingly rational principle, i.e., the need to balance physical effort (energy potential) so that expected precision skills are maintained while it is extended (in fact, a repeated use of firearms). Actually, this is what happens until the last series of shooting. The most significant sport animators, faithful to the Olympic motto: *Citius—Altius—Fortius* remain insensitive to the argumentation based on scientific knowledge. After shooting, an athlete must run until prostration. The view of athletes losing consciousness after reaching the finish line who often require premedical intervention exposes the helplessness of sport science and sport medicine to the opportunity to gain power, including the one concentrated by the media. Powerful people determine the standards of contemporary sport.

4 Limited Possibilities of Science Towards Aggressive Narrative in the Media Related to a Sports Event

Formulation of new assertions exposing the devastating impact of media on sports and promotion of violence and aggression in interpersonal relations through aggressive model of sport results in numerous examples which constitute an objective indicators of failure of mental health and social health on increasingly global scale. The issue whether this causal chain is an intended action of the most influential coordinators of social life or rather a side effect of their ignorance is difficult to determine. If the second answer is to be selected, Alfred North Whitehead was right while the stated that [29] the task of coordination is left to those who lack the strength or character to achieve success in any particular field. Specialised functions of the society are performed better but there is no vision of general direction of development. Detailed progress only increases the danger which emerges in the conditions of poor coordination.

An example sentence that in the middle of the last century tennis was associated in the public perception with the "white sport" and behaviour on the court (with clear emphasis on the respect for the defeated rival) served as a model of good behaviour, currently is only a figure of speech without any causative power. Although such sentences are expressed during scientific congresses, academic lectures and in scientific publications, they do not pass the narrow circle of contesting intellectuals. They, however, do not hold coordination positions on national and international levels, including the macro scale.

The empirical evidence of the limited possibilities of science towards lack of actual impact on the media to restore sport as the universal method of good manners is provided by the lack of social debate over *the Czestochowa Declarations 2015: HMA against MMA* (17–19 September 2015): *continuous improvement of health through martial arts as one of the most attractive form of physical activity for a human, accessible during entire life should constantly exist in public space, especially in electronic media, to balance permanent degradation of mental and social health by enhancing the promotion of mixed martial arts—contemporary, bloody gladiatorship, significant tool of education to aggression in a macro scale* [30].

Such debate should have sense in the media if it is to have truly social status. It is, however, only the introduction to the necessary decisions. It is about a real prospect of accepting such a universal method of good manners, when the ideals of Olympism irretrievably failed and there are no illusions as for the crises of values. Sport still has this potential, even though in a global sense (in many forms of activity along with institutions) it became a contradiction of the principles, respect of human dignity, honour code and good morals, law and elementary ethical standards.

If the so-called public opinion (i.e., media) does not draw attention to scientific argumentation, who is to exert impact on the most significant entities creating social reality in which the position of sport remains unique.

Czestochowa Declarations 2015: HMA against MMA were unanimously supported by the scientists from the entire world who participated in the 1st World Congress on Health and Martial Arts in Interdisciplinary Approach and represented the new subdiscipline, the science of martial arts. These scholars are recognisable due to two criteria—research qualification and black belt in martial art. Agonology and praxeology are the closest sciences to the science of martial arts which in a methodological sense means that the latter one uses achievements of the first two to establish key justifying assertions [31, 32].

Even methodologists of science should not be surprised that I have not listed sport science and sport medicine. Apart from sport, there is no other discipline of practicality in which science or sciences closely related to given practice would have problems with justifying the sense of practice-based actions undertaken. Medicine does not permit to use new drug without clinical procedures based on the methodology of the specific detailed medical discipline. It is also inconceivable that an aircraft would be placed into service without expertise of scholars representing various science engineering etc. However, the principle of *fait accompli* is still present in sport making it similar to war. No criteria of acceptable risk and responsibility are formalised for many extreme activates included in the broad definition of sport [33]. This still may be understood if the activity with extreme risk of injury or death is not directed towards another human being, but if one or two persons seek to overcome external forces (Himalayan mountaineering, rafting, tandem skydiving etc.). There is no rational explanation why people who fight in cages covered in blood like wild animals are referred to as athletes. This is an unpunished return to barbarism.

Apart from consent to neo-gladiators game, it would be absurd to deem responsible sport science and sport medicine for pathological dimension of global sport fostered by the narrative of the media. One may just as well lay this responsibility on many other sciences (sociology, psychology, pedagogy, etc.). One has to be fair. On the one hand, sport science and sport medicine have improved methods of doping, on the other they provide unique knowledge about human adaptation to extreme effort and motor perfectionism. It is sports medicine that we owe alternative health-related solutions: health-related fitness, health-related training [34].

One should be also fair in assessment whether media fulfil their educational mission. It is undeniable. Participation of the media in advancing the global effect of pathology in the sport burdens the major stream of news portals (dominated by sensation) devoted to sports with the greatest audience and promoting neo-gladiators' games under the name of "sport".

This does not change the fact that the conclusion is unambiguous and depressing: sport is so important tool for global social policy and a part of global business and also a mean to satisfy ambitions and needs of powerful people that critical scientific rationale will not stop the strongest centres of power (mainly media) from the escalating pathology sport until this pathology does not compromise power itself.

5 Conclusions

Prophylactic and therapy agonology approves neither aggressive model of sport nor doctrine to maximize activities in sport. The highest form of *prophylactic and therapy agonology* is *personal self-defence training,* and its major objective is to take care of all dimensions of health (somatic, mental, social) and optimal survival abilities. The overarching principle of this science is to optimise specific methods and means: health-related training based on safe fall exercises and martial arts (with limited preference of combat sports); elements of extreme form of physical activity; mental and intellectual training based on agonology, martial arts bibliotherapy, ethic, interdisciplinary knowledge to the extent necessary to creatively participate in training which is individually adapted to the capabilities of the candidate. The range of applications is not limited by age, sex, physical fitness, health status, etc. *Prophylactic and therapy agonology* may also be applied in broadly understood rehabilitation and geriatrics.

The mission of an expert in *personal self-defence training* exceeds the traditional understanding of the definition of master of self-defence or martial art. Motor (physical) competencies are not more important from abilities to counteract violence and aggression either in a verbal manner established by Buddha Sakyamuni or with the use of verbal or verbal and movement methods recommended by *modern agonology*. Learning of non-violence methods is not estimated for the scale in which it was used by Mahatma Gandhi who in a masterly way won with the British Empire. Non-violence in *prophylactic and therapy agonology* is one of crucial methods involved in survival abilities, because many people lack bravery and skills to counteract institutional violence or sophisticated destructive actions "structure of mutual benefits among the unworthy ones" [4].

Prophylactic and therapy agonology is thus a detailed empirical science within the framework of agonology, discipline which comprises all knowledge about struggle. Regardless of the leading role of *agonology*, theoretical justification of *prophylactic and therapy agonology* require an interdisciplinary approach, especially incorporating health science and security science. Theoretical and empirical manuscripts related to *agonology* are being published in two journals: *Archives of Budo* (eISSN 1643 8698) and *Archives of Budo Science of Martial Arts and Extreme Sports* (ISSN 2300 8822).

References

1. Kotarbiński, T.: Z zagadnień ogólnej teorii walki. Sekcja Psychologiczna Towarzystwa Wiedzy Wojskowe (From Problems of General Theory of Struggle. Psychological Section of the Military Knowledge Association). Warszawa (1938) (in Polish)
2. Krzemieniecki, L.A., Kalina, R.M.: Agon—a term connecting the theory of struggle with belles-lettres. A Perspect. Inter-disc. Res. Arch Budo. **7**, 255–265 (2011)

3. Kalina, R.M.: Agonology as a deeply esoteric science—an introduction to martial arts therapy on a global scale. Procedia Manuf. **3**, 1195–1202 (2015)
4. Kalina, R.M.: Agonology—the prospect of an effective defence of peace and unrestricted freedom of scientists. Arch Budo. **12**, 1–13 (2016)
5. Kalina, R.M.: Przeciwdziałanie agresji. Wykorzystanie sportu do zmniejszania agresywności. PTHP, Warszawa (1991) (In Polish, summary in English)
6. Kalina, R.M.: Modern agonology—inspiring role of Jigoro Kano and Tadeusz Kotarbinski in the creation and development of prophylactic and therapeutic dimension of science about struggle. Arch Budo. 12 (2016) (in press)
7. Rudniański, J.: Homo cogitans. O myśleniu twórczym i kryteriach wartości. Wydanie drugie rozszerzone. Wiedza Powszechna. Warszawa (198) (in Polish)
8. Kapuściński, R.: Soccer War. Translator Brand W, Vintage International (1992)
9. Ferlat, N.: L'ultima curva—la tragedia dello stadio Heysel. Corsi editore (1985) (in Italian)
10. Olympic Charter: In force as from 8 December 2014, Published by the International Olympic Committee—December 2014, Printing by DidWeDo S.à.r.l., Lausanne, Switzerland
11. Rüegg, K., Kuzawińska Rüegg, A., Barczyński, B.J.: Sports and scientific judo aspects in CISM (Conseil International du Sport Militaire)—1966–2011. Arch Budo. **8**(4), 251–259 (2012)
12. Edwards, D.J., Edwards, S.D., Basson, C.J.: Psychological well-being and physical self-esteem in sport and exercise. Int. J. Ment. Health Promot. **6**(1), 25–32 (2004)
13. Lundqvist, C.: Well-being in competitive sports—the feel-good factor? A review of conceptual considerations of well-being. Int. Rev. Sport Exerc. Psychol. **4**(2), 109–127 (2011)
14. Bloodworth, A., McNamee, M., Bailey, R.: Sport, physical activity and well-being: an objectivist account. Sport, Educ. Soc. **17**(4), 497–514 (2012)
15. Whitehead, A.N.: Process and Reality, Free Press, New York-London (1978) (corrected edition)
16. Kołakowski, L.: Metaphysical Horror. Basil Blackwell, Oxford (1988)
17. Heller, M.: Filozofia nauki. Wprowadzenie, WN PAT, Kraków (1992). (in Polish)
18. Babich, B.E.: Nietzsche's Philosophy of Science. State University of New York, New York (1994)
19. Lakatos, I., Feyerabend, P.K.: *Sull'orlo della scienza. Pro e contro il metodo* (a cura di: Matteo Matterlini), Raffaello Cortina Editore, Milano (1995), pp. 1–22 (in Italian)
20. Kotarbiński, T.: Elementy teorii poznania logiki formalnej i metodologii nauk. Państwowe Wydawnictwo Naukowe, Warszawa (1986). (in Polish)
21. Kalina, R.M.: Is it true: mens sana in corpore sano? CISM International Scientific Symposium: Physical Education, Sport and Health in the Armed Forces. Warsaw (1995), pp. 158–160
22. Green, R., Quanty, M.: The catharsis of aggression: an evaluation of an hypothesis, In: Berkowitz, L. (ed.) Advances in Experimental Social Psychology, vol. 10, pp. 1–36. Academic Press, New York (1977)
23. Zimbardo, P.G., Ruch, F.L.: Psychology and Life. Scott, Foresman and Company, Glenview, Illinois, United States of America (1977)
24. Witkowski, K., Maśliński, J., Stefaniak, T., Wieczorek, I.: Causes of injuries in young female judokas. Arch Budo. **8**(2), 109–116 (2012)
25. Bolach, B., Witkowski, K., Zerzut, M., Bolach, E.: Injuries and overloads in thai boxing (muay thai). Arch Budo. **11**, 339–349 (2015)
26. Kamitani, T., Nimura, Y., Nagahiro, S., Miyazaki, S., Tomatsu, T.: Catastrophic head and neck injuries in judo players in Japan from 2003 to 2010. Am. J. Sports Med. **41**(8), 1915–1921 (2013)
27. Pocecco, E., Ruedl, G., Stankovic, N., Sterkowicz, S., Boscolo Del Vecchio, F., Gutiérrez-García, C., Rousseau, R., Wolf, M., Kopp, M., Miarka, B., Menz, V., Krüsmann, P., Calmet, M., Malliaropoulos, N., Burtscher, M.: Injuries in judo: a systematic literature review including suggestions for prevention. Br. J. Sports Med. **47**, 1139–1143 (2013)

28. Yamauchi, K., Wakahara, K., Fukuta, M., Matsumoto, K., Sumi, H., Shimizu, K., Miyamoto, K.: Characteristics of upper extremity injuries sustained by falling during snowboarding: a study of 1918 cases. Am. J. Sports Med. **38**(7), 1468–1474 (2010)
29. Whitehead, A.N.: Science and the Modern World, Lowell Lecture, The Macmillan Company (1925)
30. Kalina, R.M. (ed.): Proceedings of the 1st World Congress on Health and Martial Arts in Interdisciplinary Approach, HMA 2015, 17–19 September 2015, Czestochowa, Poland. Warsaw: Archives of Budo (2015)
31. Kalina, R.M., Barczyński, B.J.: Archives of budo science of martial arts and extreme sports—a reason for this new branch. J. Arch Budo Sci. Martial Art Extreme Sport **9**, 1–9 (2013)
32. Barczyński, B.J., Kalina, R.M.: Science of martial arts—example of the dilemma in classifying new interdisciplinary sciences in the global systems of the science evaluation and the social consequences of courageous decisions. Procedia Manuf. **3**, 1203–1210 (2015)
33. Bąk, R.: Definition of extreme physical activity determined through the Delphi method. Arch Budo Sci. Martial Art Extreme Sport. **9**, 17–22 (2013)
34. Caspersen, C.J., Powell, K.E., Christenson, G.M.: Physical Activity, Exercise, and Physical Fitness: Definitionsand Distinctions for Health-Related Research, Public Health Reports, March-April (1985), pp. 126–131

Part II
Analysis of Individual and Team Sports

Analysis of Japanese Football Games by the Tracking Data and Sport Live Event Annotations

Yuji Kaneki, Yuta Misumi and Michiko Miyamoto

Abstract The purpose of this study is to learn what kind of play would lead to opportunities and to pinches, by using data from the tracking system, as well as live coverage of the real-time sport broadcasting from a game played by Shonan Bellmare and Kashima Antlers, Japanese professional football teams. In this study, we present a novel approach for sports event detection based on analysis and alignment of tracking data and real-time sport broadcasting. Based on these results of analyses, we will evaluate tactics and movements of main players from the standpoint of the better team management.

Keywords Football games · Tracking data · Real-time sport event annotations

1 Introduction

Football is one of the most popular sports in the world, and Japan is no exception. There are professional football leagues, called J-League, in Japan. J-League has more than 20 year history; it officially started its first season with ten clubs on May 15, 1993. Many Japanese players who participated in the 2014 FIFA World Cup in Brazil are currently playing in European leagues. In order to win big tournaments, football teams need to evaluate teamwork and each player's individual performance, as well as tactics, performance analysis and scouting are potential fields of application [1–4]. The purpose of this study is to learn what kind of play would lead to opportunities and to pinches, by using data from the tracking system, as well as

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live coverage of the real-time broadcasting, from a game played by Shonan Bellmare and Kashima Antlers of J-League. The tracking system intended for football games in Japan was introduced and adopted in 2015. The movement of players and balls during games can now be extracted as data. A possible effective use of this data will enable team managers to carry out accurate evaluation of tactics and players of the team. Furthermore, not only for the team, but it is also considered to be the valuable and helpful sources for viewers watching games on TV. It has already displayed hot zones and travel distances on TV by utilizing tracking data.

Not only tracking data, but extracted event keywords from the real-time sport broadcasting are considered as complementary resources in football tracking data analysis. In this study, we present a novel approach for sports event detection based on analysis and alignment of tracking data and real-time sport broadcasting. Based on these results of analyses, we will evaluate tactics and movements of main players from the standpoint of the better team management.

2 Research Background

The development of computer and video aided analysis system has enhanced accessibility to resources to analyze sporting events objectively [5]. There are a number of research projects on tracking football players [6–9]. A wide range of possible applications have been considered for football video analyses such as verification of referee decision, tactics analysis, automatic highlight identification, video annotation and browsing, content based video compression, automatic summarization of play, customized advertisement insertion, graphical object overlapping for better enjoyment of events, player and team statistic evaluations, etc. [10]. Three major application areas of football video analysis are video summarization, provision of augmented information and high-level analysis. Applications for trajectory evaluation, interaction among objects, player recognition, and event recognition are possible as high level analysis for football video analysis.

As for player and referee detection and tracking, there are many works presented covering different aspects from player segmentation and shadow removing with fixed cameras [11–13] to player classification and blob merge solution with moving cameras.

Performance analysis (PA), analyzing competitive performance of American football and basketball started in the United States, started in the 1960s [5, 14].

Kotzbek and Kain [15] propose a spatio-temporal framework from geographical perspective including several objects such as the ball, the referees' team as well as the players of two competing teams and additionally the football field and the game time. These football specific geo data have two distinguished types; i.e., tracking data and event data.

Using data collecting from GPS devices fitted to the upper back of each player using an elastic harness, Wisbey et al. [16] analyze movements of AFL footballers (n = 179) from 8 of the 16 AFL clubs during the 2008 AFL season, compared to 52 footballers in 2005, 85 in 2006 and 203 in 2007. They found that midfielders covered more distance, had higher exertion levels, and more running at higher velocities than fixed position players.

Hahm and Cho [17] suggested an approach of webcast event clustering for sport video event annotation by extracting event keyword from the webcast text.

As far as football games analyses in Japan, characteristics of attach-related game aspects within three football leagues (Japanese University Football League (JUL), Japanese professional J-League (JL) and UEFA Champions League (CL)) were analyzed and found no significant differences were observed in frequency of attacks, shots, and goals [18].

In this study, we present a novel approach for sports event detection based on analysis and alignment of tracking data and real-time sport coverage news. Based on these results of analyses, we will evaluate tactics and movements of main players from the standpoint of the better team management.

3 Research Model

The research model for this paper will be as follows (Fig. 1).

4 Data

Tracking data in this study was provided by Data Stadium Inc., Japan's leading sports information provider. Data Stadium Inc. aligns with ChyronHego [19], a global leader in broadcast graphics creation, playout, and real-time data visualization with a wide variety of products and services for live television, news, and sports production, and uses its TRACAB system. The TRACAB system is

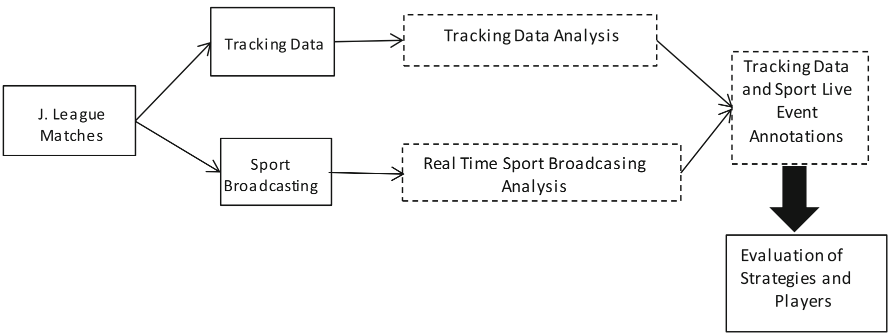

Fig. 1 The research model

Table 1 Descriptive statistics

Shonan Bellmare versus Kashima Antlers		Kashima's goal	Shonan's goal	Shonan's goal
Time of goal	Minutes	12	7	45
	Seconds	44	52	55
Half		1st	2nd	2nd
Starting half (in a series of frames)		544,559	636,068	636,068
One minute before the goal		562,159	646,368	703,443
Time of goal		563,659	647,868	704,943
		Frames	Seconds	Minutes
Shonan Bellmare versus Kashima Antlers 1st half		69,279	2771	46
Shonan Bellmare versus Kashima Antlers 2nd half		74,421	297	49

recognized as one of the most advanced camera-based player and ball tracking system on the market. TRACAB is the official tracking technology deployed by many of the major international football leagues such as the English Premier League, German Bundesliga and Spanish La Liga, as well as having been selected for the major international UEFA and FIFA tournaments. Data Stadium has just started its tracking data services for J-League in 2015. The dataset consists of football games of Shonan Bellmare versus Kashima Antlers from the J1 League, First Stage, 2nd Section 2015. Shonan Bellmare won the game. Descriptive statistics as a series of frames for starting half, 1 min before the goal, and time of the goals are shown in Table 1, and a list of players for the game are shown in Table 2.

Real-time sport coverage broadcasting was obtained from "J-League on Demand" of Sky Perfect TV [20]. J-League on Demand provides live sport coverages, as well as rebroadcasts of these games.

5 Results

5.1 Analysis of Trajectory of Players Using Tracking Data

The dataset obtained from Data Stadium Inc. contains frame numbers, system IDs, players' IDs, players' uniform numbers, x-coordinates and y-coordinates of each player's second by second location. Where x-coordinates and y-coordinates are (0, 0), it fits to the center mark on the ground. The sides of the own half or the opposition half are determined by locations of goal keepers for each team.

First, we analyze trajectories of players who involved in goals. We take frames data for 1 min before they actually made goals. Figure 2 shows a movement of player, Kanazaki (MF) of Kashima Antlers, 1 min before his goal. Takasaki

Table 2 List of players

Kashima Antlers		Shonan Bellmare	
	Starting member		*Starting member*
GK 21	Hitoshi SOGAHATA	GK 1	Yota AKIMOTO
DF 22	Daigo NISHI	DF 3	Wataru ENDO
DF 4	Kazuya YAMAMURA	DF 4	ANDRE BAHIA
DF 14	Seok Ho HWANG	DF 17	Yuto MISAO
DF 16	Shuto YAMAMOTO	MF 14	Seiya FUJITA
MF 20	Gaku SHIBASAKI	MF 2	Shunsuke KIKUCHI
MF 40	Mitsuo OGASAWARA	MF 6	Ryota NAGAKI
MF 25	Yasushi ENDO	MF 10	Daisuke KIKUCHI
MF 33	MuKANAZAKI	FW 19	Shuhei OTSUKI
MF 8	Shoma DOI	FW 9	Bruno Cesar
FW 15	Hiroyuki TAKASAKI	FW 23	Kaoru TAKAYAMA
	Substitute		*Substitute*
GK 1	Akihiro SATO	GK 21	Yuji KAJIKAWA
DF 24	Yukitoshi ITO	DF 20	Keisuke TSUBOI
DF 5	Takeshi AOKI	MF 15	Kim Jong-pil
MF 10	Masashi MOTOYAMA	DF 5	Shota KOBAYASHI
MF 13	Atsutaka NAKAMURA	FW 18	ALISON
MF 30	Hisashi OHASHI	FW 22	Shohei OKADA
MF 7	CAIO	FW 7	Yohei OTAKE
Manager	Toninho Cerezo	Manager	Cho Kwi-Jea

(FW) assisted, and Kanazaki made a goal. A larger dot shows where Kanazaki responded on Takasaki's assist.

5.2 *Word Cloud Analysis of Real Time Sport Broadcasting*

A text cloud or word cloud is a visualization of word frequency in a given text as a weighted list [21]. The more frequent the word is used, the larger and bolder it is displayed. For 1 min before each of three goals in this game, broadcasted voice data of "J-League on Demand" is analyzed.

A word cloud result for the first goal by Kashima Antlers is shown in Fig. 3; Takayama (FW) and Kikuchi (MF) of Shonan Bellmare tried to come back and return to their half in order to stop Kashima's offenses from scoring; however, Takasaki (MF) of Kashima Antlers got a ball and assisted Kanazaki (MF) to score the goal by a swift counter attack.

The second goal was a result of Penalty Kick by Endo (DF) of Shonan Bellmare, right after a corner kick. In the Kashima's penalty area, a contact play was regarded as a foul against Endo (DF; Shonan) by Ogasawara (MF: Kashima) (see Fig. 4).

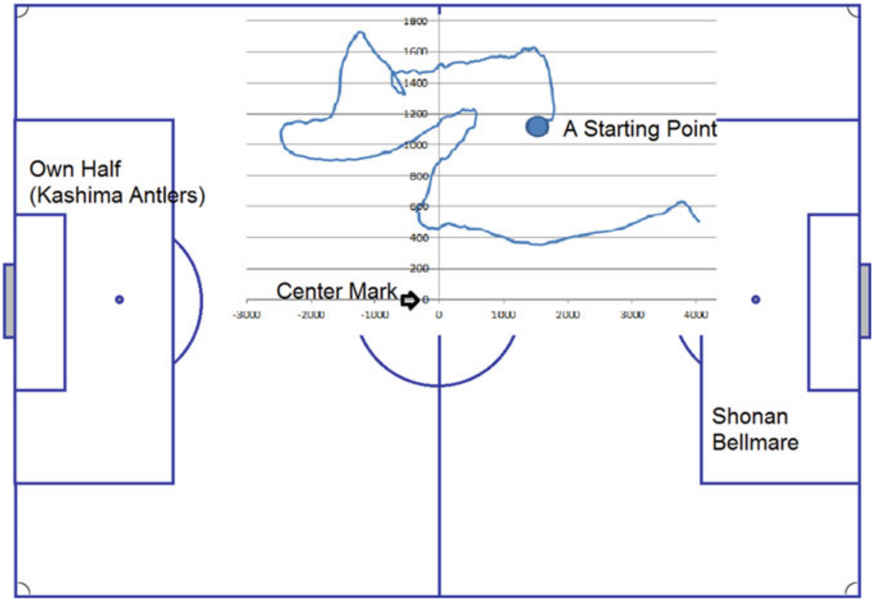

Fig. 2 Trajectory of Kanazaki (MF: Kashima Antlers) from Shonan Bellmare versus Kashima Antlers

Fig. 3 A result of word cloud for the first goal Shonan Bellmare versus Kashima Antlers

In Fig. 5, a name of “Alison” is described in the largest letter, since Alison is not only the one who made the third goal, but he was related many ball positioning. Words like “strong” and “good” are also related to Alison’s play.

Fig. 4 A result of word cloud for the second goal Shonan Bellmare versus Kashima Antlers

Fig. 5 A result of word cloud for the third Goal Shonan Bellmare versus Kashima Antlers

5.3 The Tracking Data and Sport Live Event Annotations

After extracting event keywords from live broadcasting, the event annotation is then executed to align tracking data with event information from broadcasting data. Players' trajectories and extracted event keywords of 1 min before the scores are combined. Offensive and defensive players were divided; for the offense, those who scored and assisted, as well as the movement of the ball are focused; for the defense, mainly focus on the movement of three defenders, who involved in the last play, are extracted in order to see clearly in the figures. Since the second goal was a result of a penalty kick on the foul, a trajectory of the player who fouled as well as 2 people who were near him are observed. Figure 6 represents the first goal, Fig. 7 represents the second goal, and Fig. 8 represents the third goal, from the attacking side as well as the defensing side, respectively.

As for the offense side of the first goal, by using the open space, Takasaki (FW) raised the cross from the side, and Kanazaki (MF) made a shot. In addition, Fig. 6 suggests that there are two players in the penalty area at the time to raise the cross; it is conceivable that they took the ball and quickly performed a counter attack. As for the defense side, the final positions of the three defenders are concentrated on the phrase, "through"; it implys that defenders concentrated on one of two players who were in the penalty area coming in front of them. As a result, Kanazaki's coming from the back is neglected by defenders, which led to Kanazaki's score.

The second goal is taken by Endo (DF; Shonan)'s penalty kick. With regard to the defense side, since there was a corner kick just before the foul, the players of both teams had been clustered in the penalty area. Also, when looking at the time of the foul, at the back of Ogasawara (MF), who did a foul, Yamamura (DF) had entered to cover Ogasawara. It is considered that there was no need to forcibly go to pick up the ball. The PK seems to be happened as a result of an impatience play by the Kashima side, because so many Shonan players in the penalty area.

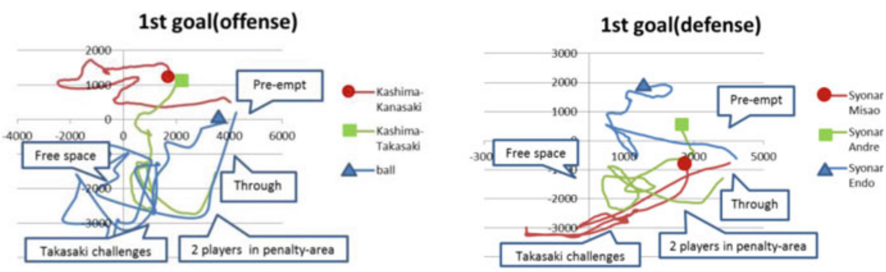

Fig. 6 The first goal

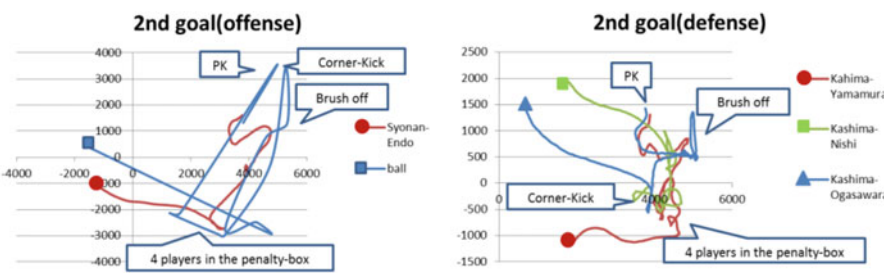

Fig. 7 The second goal

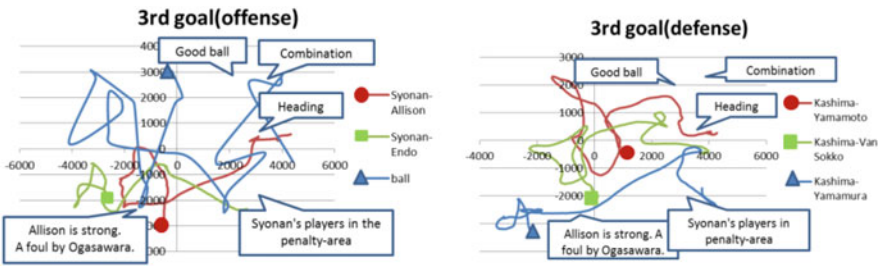

Fig. 8 The third goal

As for the third goal, Allison (FW; Shonan) scored a goal with an assist of Endo (DF; Shonan). Shonan players were moving left and right, looking for an opportunity to attack, so were defenders of Kashima, which may led to a collusion of the Kashima defense. In addition, Alison still had much physical strength, as he came to play in the middle of the game, while Kashima defenders, who had been played for 90 min, were too tired to stop him.

6 Conclusion and Implication for Managers

This paper presents a framework and empirical analyses using not only tracking data, but extracted event keywords from the real-time sport broadcasting, using data from an actual Japanese professional football game. As the development of computer and video aided analysis system has enhanced accessibility to resources to analyze sporting events objectively [5], we have gained opportunities to propose a novel approach for sports event detection based on analysis and alignment of tracking data and real-time sport broadcasting. In this study, we focused on the last minute play before the goals; however, by extracting any time of games, this framework allows managers to analyze or evaluate tactics and movements of players from the standpoint of the better team management. This is an analysis of only one game played by Shonan Bellmare and Kashima Antlers. By analyzing different games played by the same team, managers or their opponent teams may reveal the team's/rivals' strategy, trait, and tasks.

Acknowledgments This research has made use of *Data Stadium Inc*. database.

References

1. Cotta, C., Mora, A.M., Merelo, J.J., Merelo-Molina, C.: A network analysis of the 2010 FIFA world cup champion team play. J. Syst. Sci. Complex **26**, 21–42 (2013)
2. Kim, H.-C., Kwon, O., Li, K.-J.: Spatial and spatiotemporal analysis of soccer. In: Proceedings of the 19th ACM SIGSPATIAL International Conference on Advances in Geographic Information System, pp. 385–388. (2011)

3. Taki, T., Hasegawa, J., Fukumura, T.: Development of motion analysis system for quantitative evaluation of teamwork in soccer games. In: Proceedings of the International Conference in Image Processing 1996, vol. 3, pp. 815–818. (1996)
4. Vilar, L., Araújo, D., Davids, K., Bar-Yam, Y.: Science of winning soccer: emergent pattern-forming dynamics in association football. J. Syst. Sci. Complex. **26**, 73–84 (2013)
5. Carling, C., Williams, A.M., Reilly, T.: The Handbook of Soccer Match Analysis. Routledge, Abingdon, UK (2005)
6. Bebie, T., Bieri, H.: Soccer man: reconstructing soccer games from video sequences, Proc. ICPR 898–902 (1998)
7. Intille, S.S., Bobick, A.F.: Closed-world tracking, Proc. ICCV 672–678 (1995)
8. Seo, Y., Choi, S., Kim, H., Hong, K.S.: Where are the ball and players? Soccer game analysis with color based tracking and image mosaic. Proc. ICIAP 196–203 (1997)
9. Xu, M, Orwell J., Jones, G.: Tracking football players with multiple cameras. ICIP 2014, (2014)
10. D'Orazio, T., Leo, M.: A review of vision-based systems for soccer video analysis. Pattern Recogn. **43**, 2911–2926 (2010)
11. Renno, J.R., Orwell, J., Thirde, D.J., Jones, G.A.: Shadow classification and evaluation for soccer player detection. In: British Machine Vision Conference, 7–9 September, pp. 839–848. Kingston University, London (2004)
12. Kim, H., Nam, S., Kim, J.: Player segmentation evaluation for trajectory estimation in soccer games. In: Proceeding of Image and Vision Computing, 26–28 November, pp. 159–162. Palmerston North, New Zealand (2003)
13. Figueroa, P.J., Leite, N.J., Barros, L.R.M.: Background recovering in outdoor image sequences: an example of soccer player segmentation. Image Vis. Comput. **24**(4), 363–374 (2006)
14. Hughes, M.D., Franks, I.M.: Notational Analysis of Sport Second Edition—A Perspective on Improving Coaching. F. N. Spon, London (2004)
15. Kotzbek, G., Kainz, W.: Football games analysis: a new application area for cartographers and GI-Seientists? In: 5th International Conference on Carthography and GIS, pp. 299–306 (2014)
16. Wisbey, B., Montgomery, P.G., Pyne, D.B., Rattray, B.: Quantifying movement demands of AFL football using GPS tracking. J. Sci. Med. Sport. **13**(5), 531–536 (2010)
17. Hahm, G-J., Cho. K.: An approach of webcast event clustering for sport video event annotation. In: Proceedings of the International Conference on Information and Communication Technology Convergence (ICTC) 2015, pp. 849–851 (2015)
18. Nakayama, M., Haranaka, M., Sasaki, R., Tabei, R., Kuwabara, T., Hirashima, Y.: Comparative analysis of attack-related game aspects in the Japanese university football league, Japanese J-League, and UEFA champions league, comparative analysis of attack-related game aspects in the Japanese university football league, Japanese J-League. Football Sci. **12**, 58–66 (2015)
19. ChyronHego, http://chyronhego.com/. Retrieved 23 Feb. 2016
20. J-League on Demand, http://vod.skyperfectv.co.jp/feature/jleaguelivetop/. Retrieved 23 Feb. 2016
21. Lamantia, J.: Text Clouds: A New Form of Tag Cloud? March 15, (2007). Retrieved 19 Feb. 2016

Putting Together First- and Third-Person Approaches for Sport Activity Analysis: The Case of Ultra-Trail Runners' Performance Analysis

Denis Hauw, Nadège Rochat, Vincent Gesbert, Tiffany Astolfi, Roberta Antonini Philippe and Benoit Mariani

Abstract This study aimed to characterize the activity of ultra-trail runners by combining data from their personal experiences with physical measurement indicators of their running performance. Ten runners' first-person analyses of the *Tor des Geants* race were processed using course of action theory [1]. Runners' experiences were represented in a succession of macrosequences and characterized using their typical components. These were associated with third-person data about their elevation velocities assessed using motion sensors. Results showed different patterns of activity related to runners' aims and levels of performance. Three typical experiences were highlighted as frequently observed in such races and showed a strong association with overall elevation velocities. A fourth typical experience, one that followed a difficult race situation, presented finer-grained sensitivity that distinguished variations between ascent and descent velocities. Results were analyzed in relation to the sense-making process associated with routine or controlled activity.

Keywords Agentive experience · Enaction · Awareness · Course of action · Sense-making · Ultra-trail · Velocity · Time

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1 Introduction

Ultra-endurance race performances constitute sporting situations rich in data for understanding how people are able to surpass themselves. Research into sport psychology has examined the experiences of such athletes in order to understand how their ability to surpass themselves is linked to the way they manage their efforts during a race. This has shown that athletes' performances during an ultra-race can emerge from three typical activity states: preservation, survival, or revival states. The preservation state corresponds to the use of anticipatory strategies to finish the race or avoid withdrawal, such as reducing one's pace or using psychological coping strategies [2]. The survival state is defined as the consequence of the negative impact of sleep deprivation, emotional disturbance due to the duration of effort, and lost energy reserves [3]. The revival state is linked to positive mood states involving the influence of group cohesiveness among ultra-trail runners during parts of the race and self-awareness or mental stamina [4]. Succinctly, the research revealed that the two key factors for performing well in ultra-endurance events were planning the race in detail in order to control the pace and being able to cope with the inevitable survival situations which runners encounter [5].

Recent studies have also tried to further these principles by analyzing the differences between race withdrawers and finishers using an in-depth analysis of the content and ordering of such activity states. Rochat et al. [6] showed that certain relationships and ordering between the survival and preservation states allowed withdrawers to be distinguished from finishers. Antonini Philippe et al. [7] made a qualitative analysis of how runners progressively fell into the survival state, eventually pushing them to withdrawal. Hence, these in-depth analyses of activity states in relation to runners' feelings have progressively become a heuristic path towards a better understanding of the organization of such performance. However, the main limitation of all these studies was that they were exclusively centered on a first-person experience approach (i.e., a phenomenological level of analysis). Recent research in sport sciences has combined the third-person approach with analyses using a first-person approach [8]. We therefore sought to combine a third-person approach into our activity state analysis. Knowing that runners are very careful about the times they reach different key points in the race and frequently use their GPSs to monitor their velocity and effort, we chose to examine their velocity in relation to their experiences of activity states. Our research question was, "To what extent are the activity states experienced by runners associated with their real velocities during the race?"

To do this, we used course of action theory [1] and analyzed runners' activities as has been done in other sports performance studies [9, 10]. A course of action is a theoretical object that reflects the world enacted by a genuine agent in a situation. A course of action is characterized by the Elementary Units of Meaning (EUM) that mainly emerge from the association between the agent's intentional state (i.e., the range of possible actions that he or she can undertake) and the situation-related judgments of a proprioceptive, perceptive, or memory-based nature (i.e., Representamen). The course of action is thus the ordered linking together of EUM during a period of an agent's activity. It can also be characterized by emergent or higher order structures of meaning, such as sequences (i.e., a succession of EUM that corresponds to a same concern for an agent) and macro-sequences that represent the meaningful concerns of the agent during a succession of sequences.

In summary, by combining runners' first experiences with kinematic data from their race, we aimed to carry out a deeper analysis of how they "made sense" of their situation and were able to achieve different kinds of race performances.

2 Method

2.1 Participants

Ten runners between 23 and 58 years old (5 females, 5 males) volunteered to participate in this study. All had at least five years' experience in ultra-trail competitions (M = 9, SD = 2.6) and trained for an average of 80 km per week (SD = 30).

2.2 Data Collection

Data was collected during 2015 *Tor des Géants* ultra-trail race (332.5 km, 24,000 m change in elevation). There are six *life bases* distributed along the track (at 48.6, 102.1, 148.7, 200.3, 236.3, and 283.5 km). Owing to weather conditions, the race was interrupted and then definitively stopped before all the participants had finished it: at that moment, six study participants had run about 200.3 km, two had run 236.3 km, and the last two had run 283.5 km.

Three types of data were collected during the race: self-assessment data, field notes and leg movement. The self-assessments were made at the start of the race and at each life base,in order to rate: (a) the intensity of the effort carried out so far (E), (b) the level of tiredness (T), (c) the intensity of muscle damage experienced (D), and (d) the level of well-being (WB). This was done using a 10-point Likert scale for effort and 7-point Likert scales for the other assessment. Field notes related to the runners' states were recorded by the researchers during the time runners spent at each life base. They consisted of observations on the way they arrived at the life base, spent their time there, and restarted the race. Leg movement was assessed using Physilog® 4 Silver motion sensors (Gait Up SA, Lausanne, Switzerland) attached to each participant's ankle. This standalone wearable sensor incorporates a microcontroller, memory, tri-axial accelerometer (range $\pm$ 16 g-forces), tri-axial gyroscope (range $\pm$ 2000/s), barometric pressure sensor (precision of $\sim$10 cm in altitude), and a tri-axial magnetometer (disabled for this study). The sensor module is small (50 mm $\times$ 37 mm $\times$ 9.2 mm), weighs only 19 g, and has battery life up to 23 h. Batteries were changed at each life base. Accelerometer and gyroscope data were recorded with a sampling frequency of 100 Hz and the barometer was sampled at 25 Hz. The Physilog® collected each runner's elevation velocity and steps per minute throughout the race.

After the race, self-confrontation interviews were conducted by showing each runner his or her race map, recorded field notes, and self-assessment ratings at each life base. These interviews aimed to provoke the re-emergence of elements from the runners' recent past experiences when faced with traces of their own activities. As has been done in various sport studies, athletes were asked to describe, explain, and comment on their experiences, situating them within the context of the unfolding race [6, 7, 9, 10].

2.3 Data Coding

In line with previous sport sciences studies, the verbal narratives and traces of runners' past activities were coded into elementary units of activity using involvement and representamens (i.e., what was meaningful to them). These were then grouped into sequences, and then into macrosequences (MSs) in order to identify various levels of agentive experience. A succession of MSs characterized patterns in each runner's activity state [6].

We focused on each MS of each pattern by characterizing them using qualitative indicators (involvement and representamen) and quantitative data such as the distance covered and the values from the self-assessments. Each runner's average elevation velocity (i.e., ascent and descent) was also calculated. When a finer-grained analysis was needed (i.e., no significant effect had been observed), these average velocities were calculated by distinguishing between ascent and descent. Because the Physilog® recordings were continuous, data were pre-filtered using two steps: first, data under the value of 50 steps per minute were deleted (these data matched stops at life bases and nutritional resupply points); second, data for the flat sections of the race were deleted (less than 10 % of the total distance) in order to only use data corresponding to ascents and descents.

3 Results

Three patterns of running activity were identified: the *economical runner*, the *explorer runner*, and the *Kairos runner*. Below, we describe one case per pattern.

3.1 The Economical Runner

This pattern was characterized by one MS: "maintaining a very slow running speed, using each life base for recuperation" (200.3 km). The MS's involvement was

Table 1 Characteristics of economical runner macrosequence

	Self-assessment				Involvement	Representamen
	E	T	D	WB		
Maintaining a very slow running speed, using each life base for recuperation	3.8	3.6	3	5	Be careful about the pace, preserve oneself, save energy, do not get hurt	Acceptable levels of pain and fatigue, pleasure running, absence of physical pain

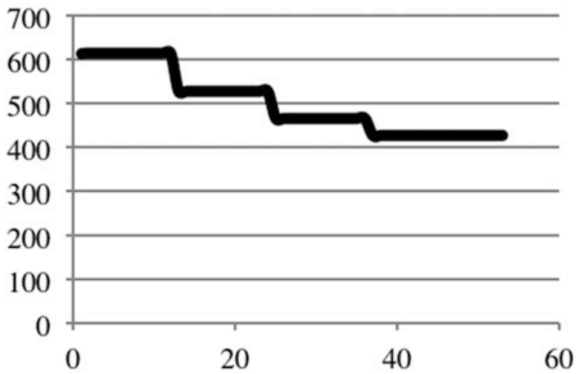

Fig. 1 The *black line* represents the evolution of the average elevation velocity between life bases for an *economical runner* (m/h) during the race

"save energy" or "preserve oneself", combined with the representamen of an absence of physical pain and an acceptable level of fatigue during the race. The *economical runner*'s self-assessment was one of feeling relatively comfortable as the race unfolded (see Table 1).

This pattern was also characterized by a progressive decrease in the average elevation velocity during the race, as shown in Fig. 1. This decreased from 614.90 m/h at the beginning of the race to 427.29 m/h when the race was suspended.

3.2 *The Explorer Runner*

This pattern was characterized by three MSs: "running without discomfort" (102.1 km); "running with sudden, extreme fatigue" (46.6 km); and "running at the best possible pace" (134.8 km) (see Table 2).

In the "running without discomfort" MS, runner tried to maintain a good pace without exhausting him/herself. Self-assessment revealed that this runner felt relatively comfortable. The "running with sudden, extreme fatigue" MS involved struggling to go on while feeling extreme fatigue. Self-assessment showed that this runner felt uncomfortable. The "running at a the best possible pace" MS consisted in giving one's best during the ascent and letting gravity take over in the descents.

Table 2 Characteristics of explorer runner macrosequences

	Self-assessment				Involvement	Representamen
	E	T	D	WB		
Running without discomfort	4.3	3.6	3	4.7	Do not blow out too early, try to maintain rhythm	Running feels easy, pleasurable, or really good, pacing oneself
Running with sudden, extreme fatigue	7	5	5	4	Hold on, struggle to go on	The cold is affecting me, not feeling well, feeling hot, suffering, legs hurting
Running at the best possible pace	6.2	4.5	4	3	Do the best I can on ascents, let gravity take over on descents	Struggling but running, feeling better, feel like I'm moving forward

Self-assessment revealed that this runner still felt uncomfortable even if some improvements emerged.

These macrosequences were also characterized using the average elevation velocity, as shown in Fig. 2. The "running without discomfort" MS was characterized by a high elevation velocity (M = 757.89 m/h). The "running with sudden, extreme fatigue" MS was characterized by a strong decrease in elevation velocity (M = 491.93 m/h). Finally, the "running at the best possible pace" MS was characterized by a weak, insignificant increase in elevation velocity in comparison to the previous one (M = 545.61 m/h).

The present results showed no significant difference between the average elevation velocity of the "running with sudden, extreme fatigue" and "running at the best possible pace" (491.93 vs. 545.61 m/h), so the average ascent and descent velocities were calculated (Table 3). Results indicated an increase in descent velocity and a decrease in ascent velocity for the "running at the best possible pace" MS compared with the "running with sudden, extreme fatigue" MS.

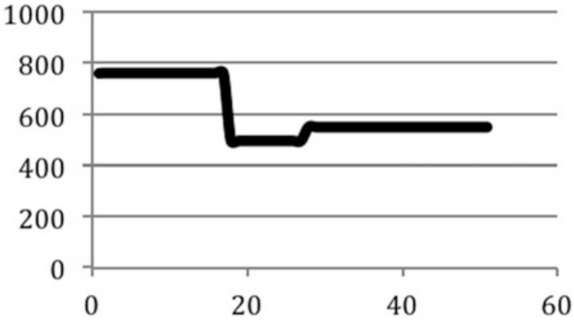

Fig. 2 The *black line* represents the evolution of the average elevation velocity between life bases for an *explorer runner* (m/h) during the race

Table 3 The ascent and descent velocities for the "running with sudden, extreme fatigue" and "running at the best possible pace" macrosequences of an explorer runner

Macrosequences	Ascent velocity (m/h)	Descent velocity (m/h)
Running with sudden, extreme fatigue	453.78	549.24
Running at the best possible pace	389.45	626.7

3.3 The Kairos Runner

This pattern was characterized by two MSs: "controlling the pace as the race unfolded" (271 km) and "accelerating to finish the race" (12.5 km). In the "controlling the pace as the race unfolded" MS runner tried to maintain a good running pace without exhaust themselves. Self-assessment showed that Kairos runner felt in a relatively comfortable zone. The "accelerating to finish the race" MS consisted in an abrupt change to the way in which the runner engaged in the situation to get ahead of his opponents and get back up the ranking. Self-assessment showed that *Kairos runner* made great efforts, however, the others elements of experience were rated at reasonable levels (Table 4).

Table 4 Characteristics of Kairos runner macrosequences

	Self-assessment				Involvement	Representamen
	E	T	D	WB		
Controlling the pace as the race unfolded	5.3	3	3	5.4	Energy to spare, do not get hurt	Running feels easy, acceptable fatigue, pleasure, absence of physical pain
Accelerating to finish the race	8	5	4	2	Lead the race, get further ahead, increase lead	Feeling of having lots of energy, very challenging weather conditions

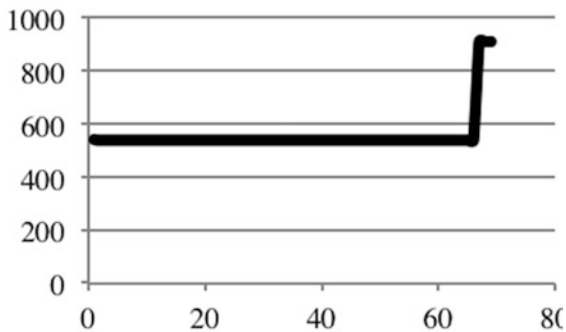

Fig. 3 The *black line* represents the evolution of the average elevation velocity between life bases for a Kairos runner (m/h) during the race

These macrosequences were characterized using the average elevation velocities (Fig. 3). The “controlling the pace as the race unfolded” MS was characterized by a stable elevation velocity (M = 535 m/h), whereas the “accelerating to finish the race” MS was characterized by a great increase in velocity values (M = 906 m/h).

4 Discussion

The different patterns presented here can be associated with various ways of managing the efforts required to complete an ultra-trail depending on the runner’s expected performance. Clearly, the first pattern corresponded to amateur runners aiming simply to participate in and finish the race. The other two patterns, however, could be associated with more competitive runners aiming for a good personal performances or a strong ranking. These results confirmed the importance of accurately managing one’s efforts and energies during such races [2, 4, 6]. They also revealed new ways of doing this.

Results showed that these means of managing effort could be organized into different sequences of experiences represented by macrosequences: these corresponded to specific types of involvement linked to the specific feelings associated with the runner’s current situation. In macrosequences, the phenomenological *thickness* of the runner’s stream of experience during the race is concentrated into a form of awareness of the situated activity or timely sense of agency [1, 11]—that is, the moment-by-moment feeling of being a runner competing in the race.

Three of the macro-sequences appeared to correlate with the values of the overall elevation velocities (including ascent and descent velocities). When runners characterized their perception of their pattern of running activity as *economical*, elevation velocity was relatively low and progressively decreased during the race. These runners were thus sensitive to the perceptual information of a low velocity, and a slow, step-by-step decrease in velocity (a decrease of 200 m/h over more than 50 h) did not affect this perception. The runners who described the feeling that activity accelerated towards the end the race saw their elevation velocity increase overall. Runners’ awareness of the current situation appeared to be linked to the same overall increase in velocity with a value that was almost a 400 m/h for a short duration. For runners who described their feeling of activity as being one of extreme fatigue, the elevation velocity showed a great decrease compared to the previous state (almost 300 m/h lower). Once again, runners’ awareness of the situation appeared to be linked to the value of the elevation velocity.

Thus, we can argue that ultra-trail runners’ awareness of their race activity is made up of the perceptual information related to the average elevation velocity that afford them during different parts of the race. The runners constructed a situational awareness in which their elevation velocities informed them about the activity state in which they were running. These results add to our understanding of the three activity states that ultra-runners experience during a race [6]. When elevation velocity values are progressively decreasing within a low range, runners’ awareness of being in a preservation state remain constant. In contrast, when elevation velocity values increased or decrease strongly, they informed runners of whether they were in revival or survival states.

The present results also revealed a fourth macrosequence labeled “running at the best possible pace.” This activity awareness emerged when runners were able to go out from a loss activity state. In this macrosequence, mean elevation velocities did not seem significantly different from the previous macrosequence in which runners felt they were in a survival state. However, a closer look at the data showed that mean ascent velocities had decreased (by 60 m/h) whereas mean descent velocities had increased in the second one (by 70 m/h). Thus, we can argue that this awareness of “running at the best possible pace” was linked to the distinction between the two types of elevation velocity—ascent (managing a relative decrease in speed) and descent (running faster). Runners’ awareness of being in a better state, of feeling better, was informed by this distinction between velocities. This result can be interpreted by saying that after being in a state of difficulty, runners had to enact a more accurate world. By trying to enact it, they used the possibilities offered by the situation (ascent and descent). These ascents and descents velocities constituted affordances and informed runners about the new states that finally makes emerging this sense.

These results are congruent with the enactive conception of human activity in which (a) routines (corresponding to the three first macrosequences, and frequently observed in trail running, e.g., [2–4]) makes emerging a global sense of activity and (b) disruptions, in order to be absorbed implies to create a new world of actions by increasing level of attention and distinguishing more and at finer grain elements available in the environment [12, 13].

To conclude, the original way in which first- and third-person data were aggregated in this study have enriched our understanding of the components of activity state awareness during an ultra-trail race. The present findings suggest the potential heuristic value of this method for future studies in sports-oriented situated activity.

References

1. Theureau, J.: le cours d’action: L’enaction et l’expérience. Octares, Toulouse (2015)
2. Holt, N.L., Kim, Y., Klein, K.: Exploring experiences of running an ultramarathon. Sport Psychol. **28**(1), 22–35 (2014)
3. Hurdiel, R., Pezé, T., Daugherty, J., Girard, J., Poussel, M., Poletti, L., et al.: Combined effects of sleep deprivation and strenuous exercise on cognitive performances during The North Face® Ultra Trail du Mont Blanc® (UTMB®). J. Sports Sci. **33**(7), 670–674 (2015)
4. Johnson, U., Kenttä, G., Ivarsson, A., Alvmyren, I., Karlsson, M.: An ultra-runner’s experience of physical and emotional challenges during a 10-week continental run. Int. J. Sport Exerc. Psychol. **21**, 1–13 (2015)
5. Lahart, I.M., Lane, A.M., Hulton, A., Williams, K., Godfrey, R., Pedlar, C., et al.: Challenges in maintaining emotion regulation in a sleep and energy deprived state induced by the 4800 Km ultra-endurance bicycle race; the Race Across America (RAAM). J. Sports Sci. Med. **12**(3), 481–488 (2013)

6. Rochat, N., Hauw, D., Antonini Philippe, R., Crettaz von Roten, F., Seifert, L.: Comparison of energetics states of finisher and withdrawer trail runners using the course of experience framework. Manuscript submitted to publication
7. Antonini Philippe, R., Rochat, N., Hauw, D.: The story of withdrawals in ultra trail running race: a dynamics and qualitative investigation of the trailers' experience. Manuscript submitted to publication
8. Sève, C., Nordez, A., Poizat, G., Saury, J.: Performance analysis in sport: contributions from a joint analysis of athletes' experience and biomechanical indicators. Scand. J. Med. Sci. Sports **23**(5), 576–584 (2013)
9. Hauw, D., Durand, M.: Situated analysis of elite trampolinists' problems in competition using retrospective interviews. J. Sports Sci. **25**(2), 173–183 (2007)
10. Hauw, D., Mohamed, S.: Patterns in the situated activity of substance use in the careers of elite doping athletes. Psychol. Sport Exerc. **16**(2), 156–163 (2015)
11. Pacherie, E.: Time to act: the dynamics of agentive experiences. In: Eitam, B., Haggard, P. (eds.) The Sense of Agency, pp. 3–24. Oxford University Press, Oxford (2015)
12. Varela, F.J., Shear, J.: The View from Within. Inprint Academic, Thoverton (1999)
13. Stewart, J.O., Gapenne, O., Di Paolo, E.A.: Enaction: Toward a New Paradigm for Cognitive Science. MIT Press, Cambridge (2014)

Automatic Exercise Counting and Calorie Calculation for Outdoor Exercise Equipment in the Park

Sang-Kyun Kim and Kyong Sik Choi

Abstract In this paper, we present algorithms that automatically count the number of repetitions and calculate the calories consumed on outdoor exercise equipment. Using sensed data from a tri-axial accelerometer, the proposed algorithm can reliably measure the number of repetitions on four different outdoor fitness machines. Using the same accelerometer, a calorie calculation algorithm for a lateral pull-down machine is also proposed. The experimental results prove that the proposed algorithm is robust to any deformation of the sensor direction as well as various types of exercise patterns. The average accuracy of the counting algorithm is 0.9722 (97.22 %).

Keywords U-wellness health park · Outdoor fitness machine · Automatic exercise count measure · Automatic calorie calculation · Tri-axial accelerometer

1 Introduction

Recently many wellness-related systems and services have been developed and released in the market, not only for the elderly but also for the general public. These systems and services mainly aim to prevent disease and to help people maintain healthy lives. USN-based Health Park [1] is one of them. The park uses sensors attached to exercise equipment to check the health status of individual and to measure the amount of exercise they do.

An existing wellness-related system offering a personal exercise program is Fitlinxx [2]. Fitlinxx includes indoor fitness machines with attached sensors that can measure the number of repetitions. No technical details about Fitlinxx have been

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disclosed to the public. Fitlinxx, however, cannot easily be adopted for outdoor fitness applications, as its components include rubber belts, which are easily broken or deformed by forces and/or climate changes in outdoor environments.

Manne et al. [3] reported the applicability of a tri-axial accelerometer to measure the energy expended while lifting weights. A tri-axial accelerometer was embedded in a wristwatch to measure the number of repetitions by measuring movement distances. The accuracy (i.e., variation estimation: 14–32 %) of measuring the movement distances in this study was not very reliable as the movements during the weight lifting activity included rotational movements and because the actual moving distances were not properly compared with the calculated results.

Other research [4, 5] focused on measuring the number of repetitions from outdoor fitness machines using a tri-axial accelerometer as well, but there were no details about how to accomplish the task. Choi et al. [6] presented an algorithm to count the number of repetitions on outdoor fitness machines, but they did not demonstrate how to calculate the amount of the calories consumed automatically on such machines.

In this paper, we present a method that counts the number of repetitions and calculates the amount of calories consumed on outdoor fitness machines. The novelty of this paper is in the three following aspects. This paper represents the first method able to calculate the number of repetitions and the amount of calories used simultaneously on outdoor fitness machines in a park using a tri-axial accelerometer. Second, the method presented in this paper is robust enough to overcome harsh conditions (e.g., forces, weather, and noise) of outside environments and to manage a variety of exercise patterns successfully (e.g., exercise paces and ranges). Third, the proposed method is entirely non-interruptive and noninvasive as it only involves attaching a tri-axial accelerometer onto outdoor fitness machines.

This paper is organized as follows. Section 2 explains the details of the proposed method for counting the number of exercise repetitions and calculating calories consumed. Section 3 presents the experimental settings, procedures, and results. Finally, the paper is concluded in Sect. 4.

2 Sensing Data from Outdoor Fitness Equipment

2.1 Counting the Number of Exercises

Figure 1 shows sensed data from a tri-axial accelerometer. This type of sensor was chosen because it (1) can acquire acceleration data over time, (2) is relatively inexpensive and easy to install, and because (3) the data from a tri-axial accelerometer is robust to deformation of the sensor direction. In spite of any rotation of the sensor in any direction due to the continuous impact of the sensor over time, the tri-axial accelerometer will produce consistent data.

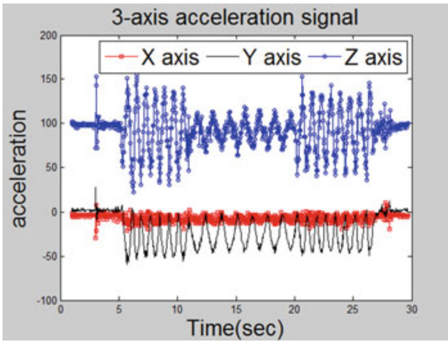

Fig. 1 Sensed data from a tri-axial accelerometer

Figure 2 presents the overall algorithm flow for counting the number of repetitions. The algorithm is composed of four main stages: a preprocessing stage, an exercise region detection stage, an exercise region partitioning stage, and an exercise counting stage. Details about each stage are presented in the following sections.

Preprocessing. The preprocessing stage includes three sub-steps, as described below.

First, a threshold of non-exercise noise is estimated from the raw acceleration data of non-exercise states. The non-exercise noise can occur when a user remains still or moves only slightly on the equipment. The noise includes slight vibrations from the adjacent fitness machines. Figure 3 presents examples of non-exercise noise acquired from four outdoor fitness machines. These examples of non-exercise noise were collected separately by taking the acceleration data of five different subjects who remained (e.g., sat) still or made only minor movements on the equipment.

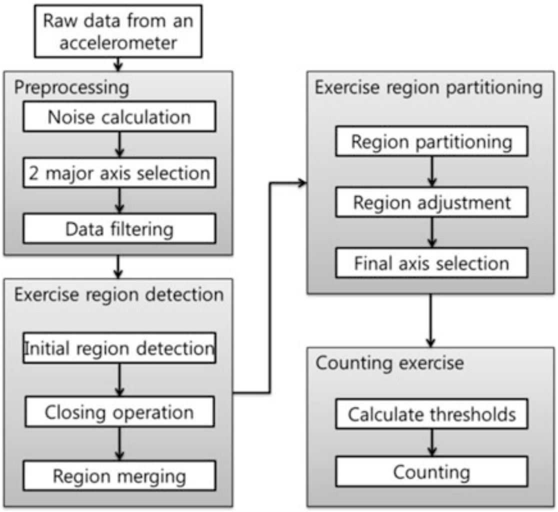

Fig. 2 Sensed data from a tri-axial accelerometer

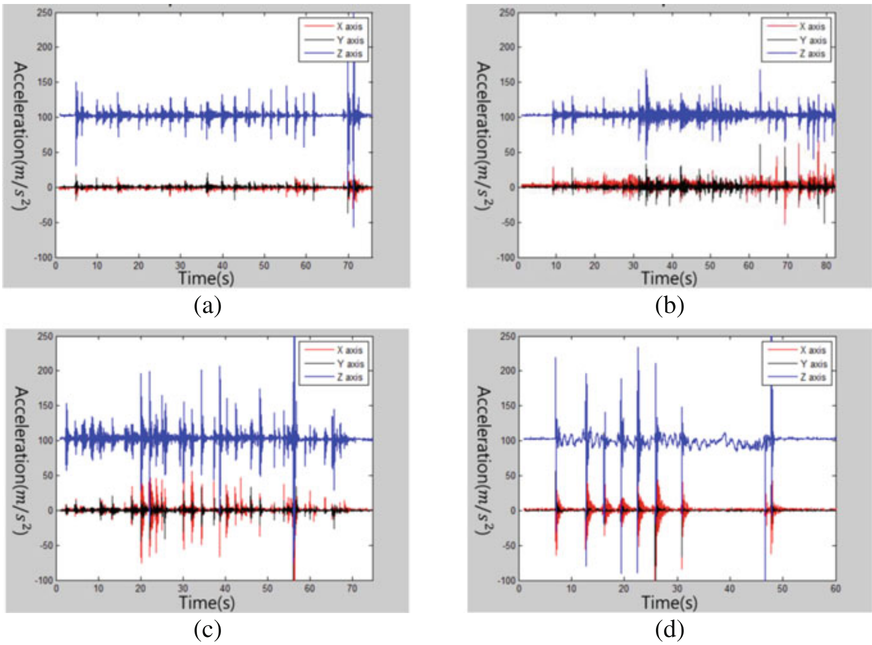

Fig. 3 Non-exercise noise data from non-exercising states

The acceleration data collected from each of the three axes have different starting points due to the acceleration of gravity, as shown in Fig. 3. The starting point of each axis is tuned to the zero acceleration position and the resulting noise data are accumulated by seeking their absolute values. An accumulative noise histogram is built and a non-exercise noise threshold is then determined using the acceleration value that accounts for 90 % of the entire noise data. The non-exercise noise in the exercise acceleration data is then removed using this calculated non-exercise threshold.

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Second, data from one axis with a minimum acceleration magnitude is then removed for a further calculation (e.g., the minimum from among $X = \sum|x|$, $Y = \sum|y|$, $Z = \sum|z|$).

$$y = \frac{1}{n - (j \times 2)} \sum_{i=j}^{n-j} x_i \quad (1)$$

Third, in order to exclude outliers and smooth the raw data, we use a filter which combines median and average filters as shown in Eq. (1). In Eq. (1), n represents the mask size (e.g., 10), j is a median boundary (e.g., 2), and the raw data x_i is sorted in an increasing order.

Exercise Region Detection.

It is important to know when a user starts and finishes exercising. The exercise region detection stage determines the entire exercise period of a user on the fitness machine.

The pink line in Fig. 4 represents actual exercising periods. The initial exercise regions (Fig. 4a) are detected using the noise threshold calculated during the pre-processing stage. To determine the actual exercise period, we merged the initial regions using morphologically close operations (Fig. 4b, c). The magnitude of the dilation and the erosion is set to one second.

Even after the morphologically close operation, there are still regions that are close enough to be regarded as a continuous exercise period. Two consecutive regions with an interval less than or equal to 2 s are merged. This means that two different people cannot work out continuously on the same fitness machine within 2 s. Figure 5 shows the result of the merging of exercise regions.

Partitioning of Exercise Regions. Acceleration magnitudes can vary with the user's exercise pace, strength, and moving distances. As shown in Fig. 6, an exercise period may contain several different paces. For example, an exercise pace (i.e., speed) of a person would be fast at the beginning of an exercise and then gradually become slower. Some people change their exercise paces intentionally during an exercise period. When paces change, the magnitudes of the acceleration are also changed. Therefore, we need to partition an exercise period in accordance with the exercise paces.

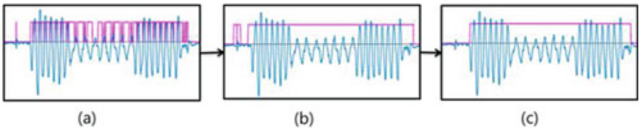
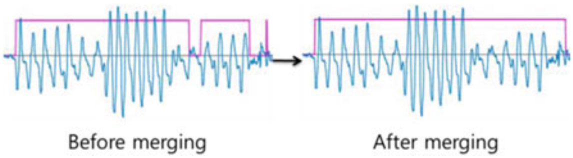


Fig. 4 Morphological close operation to determine the exercise period. **a** Original. **b** Dilation. **c** Erosion

Fig. 5 Merging of exercise regions



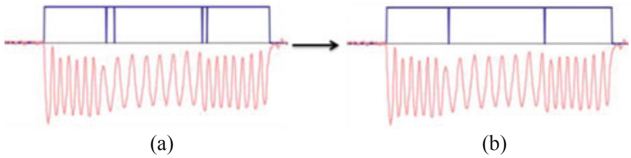


Fig. 6 Partitioning and adjustment of exercise regions

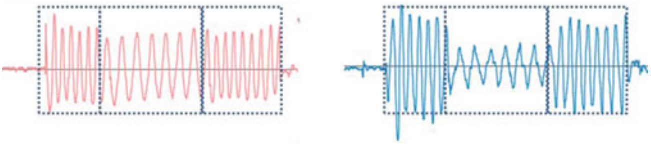


Fig. 7 Results of exercise region partitioning with various exercise paces

Figure 6 presents an example of the partitioning and adjustment of exercise regions. Partitioning occurs when the variation of the exercise speed exceeds 20 %. Partitioning generates exercise regions of less than one second, as shown in Fig. 6a. Figure 6b shows the adjustment of the short partitions. Each exercise region includes a consistent exercise pace. Figure 7 shows the results of the successful partitioning of signals with various exercise paces.

A final axis is then chosen using the data from two axes by eliminating the axis with the greater frequency. We consider that the axis with the greater frequency contains more noise. A final axis is chosen so that the proposed algorithm to be more robust to rotational changes of the accelerometer location.

Counting the Number of Repetitions. To distinguish explicit exercise movements, the threshold for each exercise region is then calculated using Otsu's threshold method [7]. Figure 8 shows the obtained thresholds using blue and pink lines. Acceleration data over a threshold becomes the data used to count the number of repetitions.

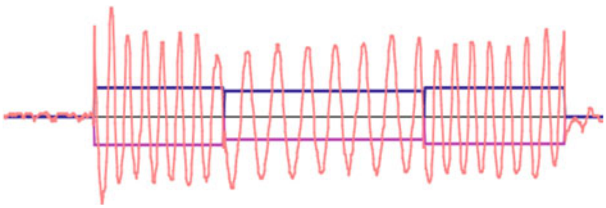


Fig. 8 Calculating the thresholds for each exercise partition

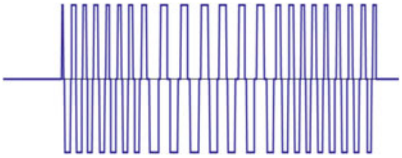


Fig. 9 Oscillation patterns generated by thresholding

$$y = \text{if}\, x_i > 0 \begin{cases} 0, & (x_i < Plus\,Threshold) \\ 1, & (x_i \geq Plus\,Threshold) \end{cases}$$
$$\text{else} \begin{cases} 0, & (x_i < Minus\,Threshold) \\ -1, & (x_i \leq Minus\,Threshold). \end{cases} \tag{2}$$

Using the thresholds for each exercise region, Eq. (2) generates oscillation patterns, as shown in Fig. 9. One oscillation is regarded as one trial. Therefore, the number of exercise repetitions can be calculated by counting the number of oscillations.

2.2 *Automatic Calorie Calculation*

A conventional calorie calculation for an anaerobic exercise utilizes the metabolic-equivalent-of-task (MET) concept. The MET is a physiological measure that expresses the energy cost of physical activities. It is defined as the ratio of the metabolic rate during a specific physical activity to a reference metabolic rate. The higher the MET is, the stronger the physical exercise becomes. Ordinary weight-lifting exercises have a MET between 3.0 and 6.0. The calorie expenditure per hour can be calculated as shown in Eq. (3).

$$\text{kcal/h} = \text{Mass(kg)} \times \text{MET}. \tag{3}$$

Because the MET derives the average calorie consumption of people, it cannot estimate precisely the amount of calories consumed during individual anaerobic exercises.

Instead, we propose a calorie consumption estimation method using acceleration data, which can be converted to potential energy variations of the center of gravity. In turn, the potential energy variations can be converted to the amount of calories consumed. Using the amount of calories consumed to lift weights on outdoor fitness machines, the gross energy expenditure can be estimated.

Figure 10 shows the acceleration data of eight trials at a constant speed from a lateral pull-down machine.

The acceleration data are converted to velocity data by integration (Fig. 11). The result in Fig. 11 shows that velocity increases as time passes. This drift is caused by the hysteresis error of the accelerometer. Hysteresis is the delay between the action and reaction of a measuring instrument (e.g., an accelerometer). Hysteresis is the

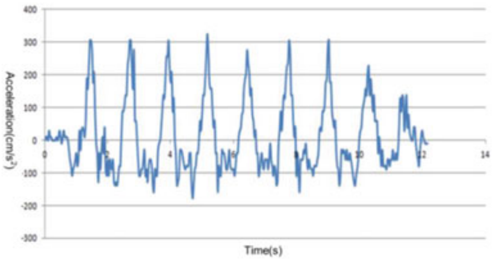


Fig. 10 Acceleration data with a constant exercise speed from a lateral pull-down machine

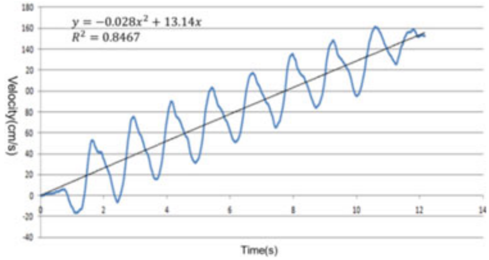


Fig. 11 A velocity graph integrating acceleration data and its trend line

amount of error that results when this action occurs. The hysteresis can be compensated for by setting a trend line, as shown in Fig. 11. The trend line is expressed with a second-degree polynomial. Figure 12 shows the corrected velocity graph using a trend line.

The velocity data can be converted to displacement data by integration. Each item of data in the graph in Fig. 13 represents the location of the center of gravity.

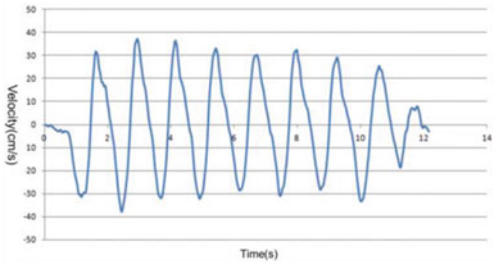


Fig. 12 A velocity graph compensated for by the trend line shown in Fig. 11

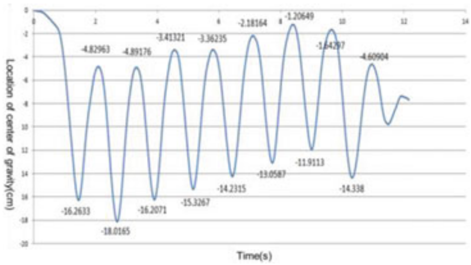


Fig. 13 A displacement graph that integrates the velocity data

The kinetic energy of exercises can be calculated by measuring the variation of the potential energy of the center of gravity. Equation (4) is the formula used for calculating the kinetic energy.

$$\mathrm{E} = \mathrm{mg} \times (\mathrm{h1} + \mathrm{h2} + \cdots + h_n). \tag{4}$$

Here, E is the kinetic energy, and its unit is the joule (J). In addition, m is the mass of an object in kilograms, g is the acceleration of gravity (9.81 m/s^2) and h is the height in meters. Given that one calorie is equivalent to 4.184 J, the calorie consumption amount can be obtained by dividing the kinetic energy (E) by 4.184. For example, if the kinetic energy of the exercise (E) is 4184 J, the amount of calories consumed to lift weights on the outdoor fitness machine becomes 1000 calories.

3 Experiment

3.1 Experimental Setting

We tested the proposed algorithm on four outdoor fitness machines, as shown in Fig. 14. The accelerometer was attached to a place where the movement magnitude was maximized. The red dots in Fig. 14 represent the locations where the accelerometer was attached.

3.2 Exercise Data Acquisition

The data was collected from five volunteers (four males and one female, height 172.8 ± 5.5 cm, weight 62.5 ± 5.5, age 25.6 ± 3.4 years, values in mean ± std), all of whom performed their exercises using the instructed exercise patterns described in Table 1. Because the volunteers had different heights and strengths, the acceleration data varied accordingly. We tested a total of 48 different exercise

(a) (b) (c) (d)

Fig. 14 Outdoor fitness machines with an accelerometer attached: **a** a lateral pull down, **b** a chest press, **c** a rowing rider, **d** an air walker

Table 1 Patterns of exercise pace combination

Pattern	Exercise pace combination				
1	Fast	→	Fast	→	Fast
2	Slow	→	Slow	→	Slow
3	Fast	→	Rest	→	Slow
4	Slow	→	Rest	→	Fast
5	Fast	→	Fast	→	Slow
6	Fast	→	Slow	→	Fast
7	Slow	→	Fast	→	Fast
8	Slow	→	Slow	→	Fast
9	Slow	→	Fast	→	Slow
10	Fast	→	Slow	→	Slow
11	Slow	→	Rest	→	Fast
12	Slow	→	Rest	→	Slow

Table 2 Test conditions of sensing directions and exercise ranges

		The angle between the sensor axis and the direction of movement	
		0°	45°
Exercise range	Short stretch	12 patterns	12 patterns
	Long stretch	12 patterns	12 patterns

conditions, which include two types of sensor attachments (Table 2), twelve exercise paces (Table 1), and two exercise ranges (Table 2). The total number of test data items for the four outdoor fitness machines was 192. Table 1 shows the twelve basic patterns of exercise pace combinations.

Table 2 shows the two different sensor attachments and two exercise ranges (i.e., a long stretch vs. a short stretch). These conditions take into account any deformations of the sensing directions and any differences in the user's physical conditions.

3.3 Experimental Results

The test results are shown in Table 3, where x is the actual number of repetitions and y is the number of repetitions calculated by the proposed algorithm.

Table 3 Test results of the proposed algorithm

$\|x - y\|$	Number of data sets	Rate
0	117	60.9375
1	67	34.89583
2	8	4.166667
Total	192	100

The experimental results are evaluated by the accuracy shown in Eq. (5). The average accuracy is calculated with Eq. (6). The average accuracy is 0.9722 (97.22 %). The standard deviation is 0.718.

$$\text{Accuracy} = \begin{cases} \frac{x}{y} & (if\ x \le y) \\ \frac{y}{x} & (else) \end{cases}. \tag{5}$$

$$\text{Average accuracy} = \frac{\sum_{i=1}^{n} Accuracy_i}{n} (n = 192). \tag{6}$$

4 Conclusion

In this paper, we presented an algorithm for converting low-level data from a tri-axial accelerometer attached to outdoor exercise equipment to the number of workout repetitions. The algorithm was tested with various types of exercise patterns (48 patterns) with four outdoor fitness machines. The experimental results showed that the average accuracy rate of the proposed algorithm exceeded 97 % between the counting of the actual repetitions and counting using the proposed algorithm.

In the future, we plan to expand our research to investigate automatically counting the number of repetitions and calculating calories consumed on a variety of outdoor fitness machines. Because the attachment locations of the tri-axial accelerometers are currently different between the counting of the number of repetitions and the calorie calculations, a method to overcome this problem will be sought.

Acknowledgments This work was supported by the ICT R&D program of MSIP/IITP. [B0126-15-1013, Development of generation and consumption of Jigsaw-liked Ultra-Wide Viewing Spacial Media].

References

1. Ro, Y., Joe, J., Ju, H., Park, H., Chun, J.: Health-park: an RFID-based Exercise and Nutritional Management System for Ubiquitous Wellness Environment. In: Proceedings of 2011 International Conference on Data Engineering and Internet Technology, pp. 834–837, Bali, Indonesia (2011)
2. Fitlinxx, http://www.fitlinxx.net/
3. Manne, H., Timo, H., Lasse, K., Juha, M., Jukka, J.: Applicability of triaxial accelerometer for energy expenditure calculation in weight lifting. In: MEMSTECH'2006, pp. 24–27 (2006)
4. Kim, S.-K., Chun, J., Kwon, D., Park, H., Ro, Y.: Interfacing sensors and virtual world health avatar application. In: NISS 2012, vol. 1, pp. 21–25, Macao (2012)

5. Kim, S.-K., Chun, J., Kwon, D., Park, H., Ro, Y.: Interfacing sensors and virtual world health avatar for U-wellness park system. JDCTA Int. J. Digit. Content Technol. Appl. **6**(13), 71–81 (2012)
6. Choi, K., Joo, Y., Kim, S.-K.: Automatic exercise counter for outdoor exercise equipment. In: 2013 IEEE International Conference on Consumer Electronics (ICCE) (2013)
7. Otsu, N.: A threshold selection method from gray-level histograms. IEEE Trans. Syst. Man Cybern. **SMC-9**(1), 62–66 (1979)

Analysis of Tools to Measure the User Experience During the Sports Practice of Recreational Surfing

Raoni Caselli, Marcelo Ferreira and Berenice Gonçalves

Abstract This research aimed to identify and analyse which tools have the greatest potential for measuring the user experience throughout the practice of recreational surfing. The method adopted to gather information was a systematic review of literature on the user experience in surfing. After analysing the selected articles, the tools with the greatest potential for measurement were highlighted. The results have shown that there are several ways to measure the user experience in different sports and in surfing. This led to the construction of a table with the potential tools for measuring the user experience on recreational surfing, highlighting their main features, their positive and negative aspects and the justification of their possible use. In the results, the following tools stood out above all the others: GPS, accelerometer and gyroscope to measure physiological variables; and the affective diary and semi-structured interviews to measure the psychological variables of the user experience.

Keywords Recreational surfing · User experience · User experience measurement · Data tracking

1 Introduction

Surf is one of the sports that developed the most in the last years, with a high growth in the numbers of practitioners. During this period, a large amount of businesses emerged, selling especially clothes, shoes and accessories related to the

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surfing lifestyle, profiting from a moment of appreciation of the surf culture to establish themselves in a growing market, with a potential of global reach [1].

Even with these advances, surfing still has little academic research on the use of new technology and equipment in comparison to large companies that dominate the market and keep their research private, aimed at developing new products. This rapid technological development period is encouraged by a highly competitive market with research projects in technology funded worldwide [2, 3].

With this in mind, today's electronic devices become obsolete quickly giving way to increasingly advanced technologies, for example devices used to track data, using Global Positioning System (GPS) technology and inertial sensors such as the accelerometer, gyroscope, barometer, compass and magnetometer. For physical activity, they can provide information on performance and body health through statistical data [4–6].

Rip Curl Company, for instance, recently launched a Smartwatch called GPS Search, which uses GPS technology to show the surfer how many waves he surfed, the time spent in each wave, the path of each wave, his maximum speed, among other information. The data is shown in a simple way in the Smartwatch screen, but for a complete experience the product is synchronized with an application on a mobile device transferring the collected data to be viewed there [7].

UX Design, or user experience design, contributes to the development of this type of interactive product that combines both hardware and software. It focuses on studying how users perceive and interact physically and emotionally with products, services and objects [8, 9]. UX Design has become very relevant in recent years, being the basis of many examples of products that sought to create a more complete user experience, involving not only the physical dimension of interaction, but also the subjective user aspects, responsible for guiding their desires and motivations [10, 11].

This research sought to demonstrate which user experience measuring tools have the greater potential to be applied in the development of products and services that contribute to the improvement of performance in recreational surfing. The results will serve as a reference when choosing the right tools, reducing the time spent researching on this selection stage.

2 Methodology

The method used for this research was the exploratory with a qualitative approach. According to [12], the main purpose of exploratory research is to develop, clarify and modify concepts and ideas, with the goal of formulating more specific problems.

The data was collected from a systematic review of literature through bibliographical research divided into two stages: systematic review of literature on the user experience in surfing and analysis of selected articles and tools identified in each, highlighting those with higher potential to be used to measure the UX on recreational surfing.

The systematic review of literature sought to identify how the user experience is measured in the practice of different sports and which user experience measurement tools can be applied to the steps involved throughout the practice of recreational surfing.

Articles analysed, dated between January 2001 and June 2015, were published in journals, international conferences and books in English, Portuguese and Spanish, from the databases ISI Web of Science (Thomson Reuters), Scopus (Elsevier) and Science Direct (Elsevier). In the several researches performed, the best terms to be used were sought. Although seemingly broad, the results showed that the combination of terms representing UX Design ("user experience", user experience design, usability and "interaction design") together with sport*, were able to return a selection of articles relevant to the research goals.

For the selection of articles, the qualifying criteria applied included: the number of citations; JCR of the published journal; latest date, and use of tools to measure aspects of the user experience in any sport. Twenty-three articles to be analysed were selected from a prior list of sixty-eight, seeking to meet the specific objectives: organization of the tools found in categories and identification of the ones most appropriate to measure the user experience on recreational surfing during the sports practice.

After the tools distribution in the identified categories, their analysis were carried out taking into account their objectives, the technologies they use and how the data is displayed. Finally, a diagram was built highlighting the tools most appropriate and with the greatest potential to measure the user experience throughout the practice of recreational surfing.

3 Results

Three main categories for the classification of selected articles were created, discriminated as objectives of data tracking, technology used for tracking and means of data visualization.

The objectives of data tracking were developed from the main demands of physical activity found in each research, also securing the use of technologies that best fit these demands. The data visualization mode was distributed according to their use by the researcher and the participants involved in the research, classifying articles by their objective, technology used and the data visualization mode.

The use of a GPS (Global Positioning System) to track the performance of the sportsman was adopted by the following authors: [13–24]. Research indicates that this technology was used to monitor the sites covered by the athlete, measure the speeds obtained in the paths, measure the total distance travelled, total time and the time spent on various activities performed during the sports practice. To view this data, most of the researches made use of the computer program distributed by the used GPS's manufacturer [7, 14, 18–23] together with data manipulation programs such as Microsoft Excel [7, 19, 20, 23]. The use of mobile applications [13, 16], website [18] and a software developed during the research [21] were also observed to analyse the data. Since GPS uses orbiting satellites to record its data, the activities were carried out in open space aiming to reach the largest possible number of satellites.

All the researches that made use of a GPS, with the exception of the research of [21], also used other sensors combined such as accelerometers, gyroscopes, digital compasses, magnetometers and temperature sensors.

The authors [25–28] used only inertial sensors in their research in order to identify variables, related to the monitoring of muscle resistance, energy expenditure and the execution of techniques, from the accelerations and changes in direction performed by the athlete. These data allows that the techniques be classified using pattern-matching algorithms.

Ahmadi et al. [29] and Mcnitt-Gray et al. [30] used a video recording technique combined with markers for biomechanical analysis of the exercise, in order to compare with the data generated by inertial sensors. The research of [30] shows that the data collected by the sensors were not as accurate as those observed by the video capture, identifying that although they are very efficient in collecting and analysing data, the inertial sensors used still do not have a degree of precision as high when compared to video analysis. The research of [29] has shown the two ways to collect data independently, not correlating the data from both. The authors chose to study experiments conducted by other researchers, comparing the results of both and showing that the inertial sensors, especially the accelerometers, have the advantage of not requiring that the experiment be performed in the laboratory, allowing their use in the actual environment where the sport is practiced. They also found that the sensors are small and light enough to be placed in any area of the body without harming the performance and its cost-effectiveness is very high when compared to other technologies such as video.

The research of [31] did not use a GPS or inertial sensors to track data. Instead, they used only a heart monitor and daily reports from the participants themselves. Just using a heart rate monitor, the study was able to track a series of data relevant to the performance, corresponding to the defined categories: duration of physical activity; maximum and average heart rate; energy expenditure in calories; calories burnt as fat; and how much time was spent on each heart rate zone.

Tran et al. [32] performed laboratory tests to assess physical performance of professional athletes from the junior category and compare the results between two groups: athletes who have been selected to represent Australia at the ISA (International Surfing Association) World Junior Surfing Championship; and athletes who were not selected. Although the tools used do not allow their use during the actual surfing activity, the variables measured are useful as a reference for defining metrics of physical performance during surfing. The article uses burst tests to measure the speed reached by the athletes paddling on a board at distances of 5, 10 and 15 m and resistance tests to measure the average speed reached during the paddling at a distance of 400 m. These data were considered very important to determine part of the physical performance of athletes that allows for comparison between the two groups.

One type of tool also very explored by the researchers was the use of semi-structured interviews and personal accounts of participants. Some of the reports were carried out as an administration of training [33] while others followed the form of interviews or diaries with the subjective opinions of participants [31, 34]. The training administration allowed the collection and analysis of quantitative data regarding the practice while interviews and diaries allowed the collection and analysis of qualitative data from the participant's physical performance. The quantitative data regarded the total time of physical activity and frequency of practice on these activities, with the additional of enabling the participants to plan their training in an organized way, to extract what was necessary and possible within the practice conditions.

3.1 Discussion

The results found in the analysis of the articles in the literature systematic review demonstrated the diversity of ways to measure the user experience in different sports using different tools with different goals. The decision-making process to identify and highlight the main tools was based mainly on the variables identified in each research that allowed access to the physical performance of athletes. Excluding some research that sought to identify factors related to user motivation, all others aimed to uncover ways to evaluate the performance of participants, selecting, testing and presenting the results with the use of one or more tools, such as the GPS, accelerometer, gyroscope, other electronic sensors, heart rate monitor, electronic diary, semi-structured interviews and video recording.

Based on this study, to evaluate the potential of the tools presented for measuring the user experience on recreational surfing, first it is necessary to determine which factors are relevant for the surfer's physical performance, selecting those that best fit the context of the sports practice and are accessible to be measured. The research of [32] can be used as a reference point in the selection of these factors, as it presents data showing that speed is a very important aspect to measure in the physical performance of surfers. The authors mention in their research that [35] also found a strong correlation between the speeds found in explosive tests and endurance test as important factors to demonstrate the difference in performance between the two groups of athletes. Tran et al. [32] discusses in their research that the explosive paddle is an important performance factor since a surfer that reaches a higher speed than his competitor will have an advantage in any form of paddling in a competition against two to four surfers. Surfers with more powerful paddlings can choose to sit deeper in the outside as their paddling ability allows them to catch waves before they reach the break zone. Tactically it allows them to choose the first wave they want to surf, therefore controlling the lineup. In addition, by sitting further back and entering the wave before, the first maneuver will be carried out in the most critical part of the wave and with great speed, maximizing the performance judging criteria established in the sport. The authors point out that possessing greater aerobic capacity benefits surfers by improving their muscle endurance for paddling and delaying the effect of fatigue on their physical performance, since paddling represents 44–54 % of the time spent during surfing.

Farley et al. [36] also reported the importance of paddling in surfing, explaining how there are different types of paddling during a session that are characterized by different physical activity intensity. The types of paddling are separated into paddling through the waves until you reach the break zone; remain well positioned to catch good waves and explosive paddling to enter the wave. Meir et al. [37] presents in their study a table with the variables that affect the heart rate and exercise intensity on recreational surfing, highlighting in the "physiological" category the following variables: distance paddling to the outside; time paddling, total and average; time standing still, total and average; muscle mass involved; and level of physical activity and age. In the "psychological" category, the highlighted variables are size and type of wave, number of waves ridden, emotional state and total number of participants.

Following the line of thought of [37], Table 1 was built to select the variables considered important to measure the surfer's performance and hence the user experience during sports practice.

The environmental variables related to the ocean and winds can be found in the websites of government agencies that monitor the climate and oceans but also in the websites of private companies such as *Windguru.*[1] The rest of the environmental and all of the psychological variables can be assessed through personal accounts of surfers about their decisions, judgements and opinions. According to [31, 34], these qualitative data can be collected by the use of affective diaries[2] or semi-structured interviews. In their research, the qualitative data described the practitioner's personal opinion and motivation from the impact of data tracking. This type of technique allows the practitioner to describe the emotions experienced during the sports practice, showing the positive and negative touchpoints and their impact in the user's motivation. The data was used in the research to verify the impact of data tracking on the user experience, whether it is positive or negative and how much it affects both. This showed it to be an interesting tool to be applied together with data tracking.

The biggest challenge lies on the collection of physiological variables data. Since it is an adventurous sport performed in the ocean, the use of tools that use electronic devices is limited by the use of waterproof protection. In addition, size and weight of such devices should be limited as to not influence the surfer's performance [24].

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[1]Available in: http://www.windguru.cz/pt/.

[2]This data collection technique is characterized by the use of sensors that track and record the physical states of the user in a smartphone so they can see it later and add their own reflections about the data. Available in: http://www.allaboutux.org/affective-diary.

Table 1 Environmental, physiological and psychological variables found in the user experience during surf practice

Environmental	Physiological	Psychological
Time of the day	Distance and time paddling to the outside	Size, direction and type of wave
Type of ocean bottom	Distance and time paddling to enter waves	Wind direction (offshore, onshore and side wind)
Distance to the outside	Distance and time paddling for positioning in the outside	Number of waves ridden
Water temperature	Average and maximum speed paddling to the outside	Emotional state
Air temperature	Average and maximum speed paddling to enter waves	Approximate number of participants
Tide height	Average and maximum speed paddling for positioning in the outside	Self-evaluation on performance
Waves period	Total distance paddling	How long has been surfing
Waves direction	Average and total paddling time	Surfer's technical level
Wind direction and intensity	Average and total standing still time	
Board's size and type used (with fins information)	Average and total time riding waves	
	Average and total distance riding waves	
	Average and maximum speed riding waves	
	Total amount of duck dives	
	Total amount of falling in waves	
	Calories burnt during physical activity	
	Surfer's stats (height, weight and age)	

One way to classify and analyse the physiological variables is with the use of speeds and accelerations zones, as shown in studies [13–15, 19, 20, 23]. The authors used these tracks to determine the types of performed physical activities as well as its intensity by analysing the time and distance travelled and spent on each zone. In surfing, the use of speed zones can be very useful to determine the types of performed paddlings, the distance and time spent on each one, the amount of waves ridden, the time and distance spent in each wave and the time spent waiting for waves. These data require at least the use of a GPS to be tracked, however to obtain more accurate data, it is necessary also the use of an accelerometer and gyroscope. Other sensors could also be used together such as digital compasses and magnetometers, which are used to improve the accuracy of the GPS.

Besides the speed and acceleration zones, the classification of zones can be achieved by using the surfer's geolocation data, dividing the zones in inside and outside. This would help in the classification of different paddlings and would allow the differentiation of surfed waves between inside waves and outside waves, with the main difference between them being the size of the wave. The use of a GPS can also be helpful to view the surfer's positioning on the outside and on the waves ridden by visualizing the geolocation data in a software or website such as Google Earth, as was used by [21]. The use of the accelerometer and gyroscope also enables the measurement of how many times the surfer duck dives a wave (surfer dives along with the board to pass beneath the waves and continue towards the outside zone) and the number of times the surfer falls from a wave after trying to stand up.

These data are collected using movement patterns, described in the researches of [13, 22–28]. These patterns are obtained by collecting accelerometer and gyroscope data while the surfer performs the technique repeated times, seeking to create a range of acceleration values and angular velocity in three-axis direction (x, y and z). It is possible that this method of tracking and analysing data can also be used to identify and classify the maneuvers performed by surfers as they ride the waves. However since these are movements with much higher degrees of complexity and very similar to each other, this method would require a team of professionals to create the classification algorithms of each maneuver and test them until they are accurate enough to be presented to users. In addition, this would require tools with a high precision, which also implies in a high cost. So far no studies were found that describes this use in surfing and since this requires a high degree of technical knowledge, this study will not cover the method due to the existing limitations.

The use of an accelerometer and a heart monitor allows the total amount of calories burnt during the physical activity to be measured, which is an extra motivational factor for many surfers who can benefit from this information when creating diets and training practices focused in body health. According to [37] the energy consumption of survey participants during an hour of recreational surfing practice varied between 1650 and 2615 kJ (394–625 kcal), which can be compared to various other activities such as canoeing (6.4 km/h), cycling (20.8 km/h), tennis and swimming freestyle. The authors suggest that surfing is a sport able to develop and maintain a positive body health, turning the calories burnt in a positive factor to measure that can affect the physical performance.

Figure 1 highlights the tools with the greatest potential for measuring the user experience in surfing, its positive and negative aspects and the reason they were chosen to measure the identified variables.

The choice of using the GPS, accelerometer and gyroscope was made because they are already found together in several existing commercial solutions, including the current Smartphones models, and also because they can collect almost all of the physiological variables data in surfing. While they need a protection against water and cold, they are small and light enough to minimize their impact on the surfer's

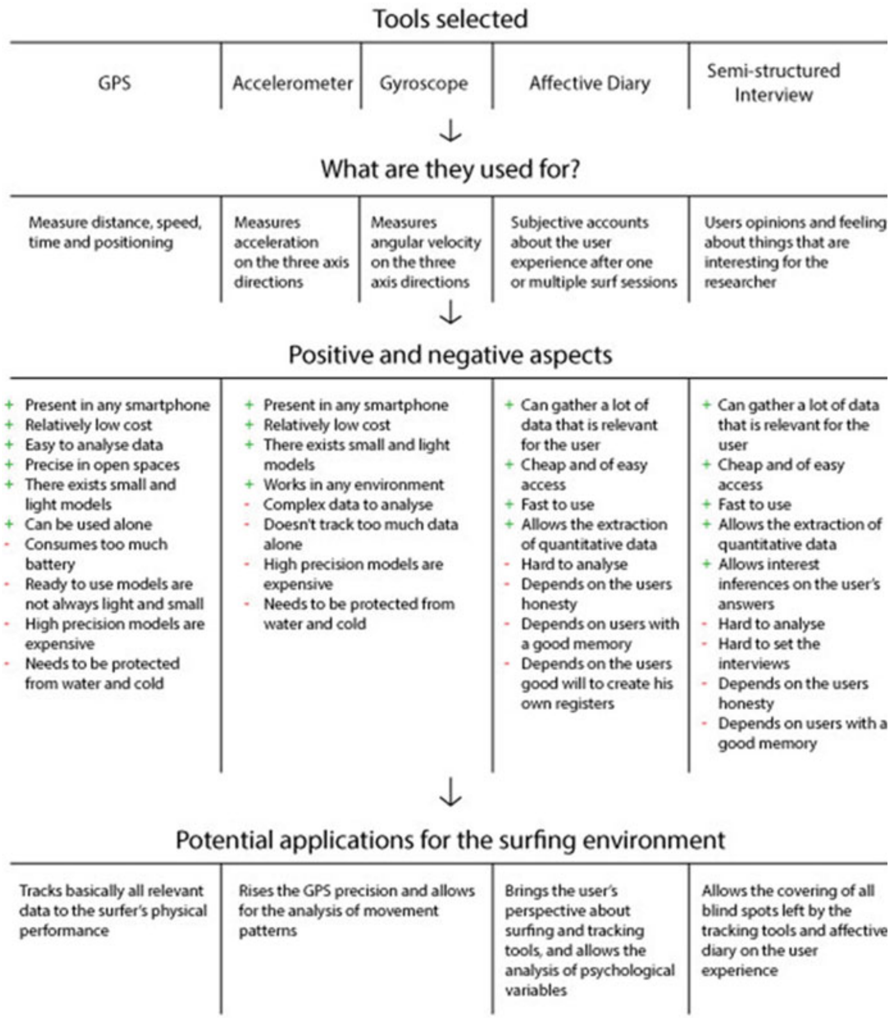

Fig. 1 Tools chosen with the highest potential for measuring the user experience during surfing

performance. They can be placed inside the wetsuit in the chest, back or arms regions, so they are trapped, do not disrupts movements and still receive extra protection from water and cold. In this case the only downside is the loss of accuracy in capturing the accelerometer and gyroscope data related to movements made by the surfer as these points may suffer more sudden changes during sports activities (such as falls, imbalances, trunk rotations) which are more unpredictable and harder to categorize by data tracking algorithms. Other alternatives include the use of products already on the market, which have both GPS and the sensors, such as the *Trace*[3] product, that is fixed on the board near the nose and the smart watch Rip Curl GPS Search. Both products use a mobile application for Android or iOS where they present the data already processed and analysed for surfer's sessions.

The indication of the affective diary and semi-structured interview may seem strange because both collect qualitative data not allowing direct measurement variables as with other selected tools. However, qualitative data can be analysed quantitatively allowing the extraction of important implications for a more complete assessment of the user experience for recreational surfing. In addition, both allow the user to analyze the use of tracking tools and the impact on their physical performance after the activity.

4 Conclusion

The combination of the five tools presented enables a completer assessment of the user experience by accessing not only the data on the physical performance, but also data on the emotions and feelings experienced during the sports practice and after it, comparing the sensations experienced by the user with the data tracked by GPS and inertial sensors. This comparison should lead to interesting insights for both the user and the researcher as they both discover more information about the user experience during the practice of recreational surfing.

The diagram constructed should be useful as a theoretical framework in the choice of tools for measuring the user experience on recreational surfing, decreasing the time spent by the researcher to research about these tools to check which would be most relevant to their research. It is expected that the identified variables represent accurately the context of user experience in surfing, ensuring the tools selected to be the most appropriate to measure the entire experience, or at least most of it.

The next research step could test the tools chosen to ensure their importance to measure the user experience on recreational surfing, allowing the development of an application method, further facilitating the application of tools. Another step could be focused on developing solutions that integrate the data of the tools in one place, giving the user the data already analysed on their physical performance, so that the user can then apply its own account of how was the practical experience during and after it happened. These solutions could even be developed from existing platforms thus eliminating rework on creating something new when there are existing alternatives.

This work represents a breakthrough in the study of the user experience in surfing and adventurous sports in nature in general. It brings to the scientific community an analysis of different tools for measuring the user experience in sports and its application on surfing. In general, the challenges found were related to the

[3]Product developed by the company *AlpineReplay* for surfers and snowboarders to track their sessions and synchronize with their videos. http://www.traceup.com/trace-for-surfing.

lack of specific content related directly to the subject of this work, characterizing it as an unprecedented publication. We hope its publication will encourage other researchers to develop more this subject so that further and relevant discussions are produced for both user experience design in surfing and for adventurous sports in nature in general.

References

1. Brasil, V.Z., Ramos, V., Terme, A.A.: O surf como esporte moderno: uma proposta de taxonomia. Buenos Aires: Revista Digital, vol. 15, n. 145 (2010)
2. Brasil, V.Z., Ramos, V., Goda, C.: A produção científica sobre surf: Uma análise a partir das publicações entre 2000–2011. Goiânia: Pensar a Prática, vol. 16, n. 3, pp. 619–955 (2013)
3. Myers, B.A.: A brief history of human computer interaction technology. ACM Interact. **5**(2), 44–54 (1998)
4. Ahtinen, A., et al.: Tracking Outdoor Sports–User Experience Perspective. In: Aarts, E., Crowley, J.L., Ruyter, B., Gerhauser, H., Pflaum, A., Schmidt, J., Wichert, R. (eds.) Ambient Intelligence: Proceedings European Conference (AmI), 19–22 Nov 2008, pp. 192–209. Nuremberg. Springer, Berlin (2008)
5. Guo, F., et al.: An evaluation of wearable activity monitoring devices. In: Singh, V.K., Chua, T., Jain, R., Pentland, A.S. (eds.) MM'13 ACM Multimedia Conference: Proceedings of the 1st ACM international workshop on Personal data meets distributed multimedia, 2013, pp. 31–34. Barcelona. ACM, New York (2013)
6. Oh, J., Lee, U.: Exploring UX issues in Quantified Self technologies. In: Proceedings of the Eighth International Conference on Mobile Computing and Ubiquitous Networking (ICMU), 2015, pp. 53–59, Hokadate. IEEE (2015)
7. Moraes, R.F.L.: Rip Curl lança o SearchGPS, o seu próprio wearable para surfistas. TecMundo, 2014, http://www.tecmundo.com.br/smartwatch/60006-rip-curl-lanca-searchgps-o-proprio-wearable-surfistas.htm
8. Law, E.L.-C. et al.: understanding, scoping and defining user experience: a survey approach. In: CHI '09 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 9, pp. 719–728, 2009, Boston. ACM, New York (2009)
9. Roto, V., et al.: User experience white paper: bringing clarity to the concept of user experience. http://www.allaboutux.org/files/UX-WhitePaper.pdf. (2001)
10. UX Awards: The premier awards for exceptional experience http://userexperienceawards.com/
11. UX Magazine Staff. Announcing Winners in the 2014 Design for Experience Awards. https://uxmag.com/articles/announcing-winners-in-the-2014-design-for-experience-awards
12. Gil, A. C. Métodos e técnicas de pesquisa social, pp. 14. 6 ed. Atlas, São Paulo (2008)
13. Buttussi, F., Chittaro, L.: Mopet: a context-aware and user-adaptive wearable system for fitness training. Artif. Intell. Med. **42**, 153–163 (2008)
14. Cunniffe, B., et al.: An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. J. Strength Conditioning Res. **23**(4), 1195–1203 (2009)
15. Gabbett, T.J.: GPS analysis of elite women's field hockey training and competition. J. Strength Conditioning Res. **24**, 1321–1324 (2010)
16. Taylor, K., et al.: Activity classification with smart phones for sports activities. In: Subic, A., Fuss, F.K., Alam, F., Clifton, P. (eds.) Procedia Engineering: APCST 5th Asia-Pacific Congress on Sports Technology, 13, pp. 428–433, 2011, Melbourne. Elsevier (2011)

17. Mullane, S.L., et al.: Design and implementation of a user-centric swimming performance monitoring tool. Proc. Inst. Mech. Eng. Part P J. Sports Eng. Technol. **225**, 213–229 (2011)
18. Dickson, T.J., et al.: Evaluation of the use of a GPS data-logging device in a snowsport environment. In: Subic, A., Fuss, F.K., Alam, F., Clifton, P. (eds.) Procedia Engineering: APCST 5th Asia-Pacific Congress on Sports Technology, 13, 2011, pp. 470–475. Melbourne. Elsevier (2011)
19. Coughlan, G.F., et al.: Physical game demands in elite rugby union: a global positioning system analysis and possible implications for rehabilitation. J. Orthop. Sports Phys. Ther. **41** (8), 600–605 (2011)
20. Reid, L.C., et al.: Return to play in elite rugby union: application of global positioning system technology in return-to-running programs. J. Sport Rehabil. **22**(2), 122–129 (2013)
21. Rangsee, P., Suebsombat, P., Boonyanant, P.: Simplified low-cost GPS-based tracking system for soccer practice. In: ISCIT 13th International Symposium on Communications and Information Technologies: Communication and Information Technology for New Life Style Beyond the Cloud, 13, 2013, pp. 724–728, Surat Thani. IEEE (2013)
22. Gastin, P.B., et al.: Quantification of Tackling Demands in Professional Australian Football Using Integrated Wearable Athlete Tracking Technology. Journal of Science and Medicine in Sport **16**(6), 589–593 (2013)
23. Beanland, E., et al.: Validation of GPS and accelerometer technology in swimming. Journal of Science and Medicine in Sport **17**(2), 234–238 (2013)
24. Bray-Miners, J. et al.: Biomechanics of slalom water skiing. In: IMechE 2014 Proceedings of the Institution of Mechanical Engineers Part P-Journal of Sports Engineering and Technology, vol. 229, pp. 47–57. Sage Journals, London (2014)
25. Ward, D.S., et al.: Accelerometer use in physical activity: best practices and research recommendations. Med. Sci. Sports Exerc. **37**, 582–588 (2005)
26. Salazar, A.J. et al.: An initial experience in wearable monitoring sport systems. In: ITAB Proceedings of the 10th International Conference on Information Technology and Applications in Biomedicine: Emerging Technologies for Patient Specific Healthcare, 2010, Corfu. IEEE, (2010)
27. Harle, R., Taherian, S. et al.: Towards real-time profiling of sprints using wearable pressure sensors. Comput. Commun. **35**, 650–660 (2012)
28. de Magalhaes, F.A., et al.: Wearable inertial sensors in swimming motion analysis: a systematic review. J. Sports Sci. **33**(7), 732–745 (2015)
29. Ahmadi, A., Rowlands, D.D., James, D.A.: Technology to monitor and enhance the performance of a tennis player. In: Pope, N.K.L., Kuhn, K.L., Forster, J.J.H. (eds.) Digital Sport for Performance Enhancement and Competitive Evolution. pp. 101–121. Information Science Reference, New York (2009)
30. Mcnitt-GRAY, J.L., et al.: Using technology and engineering to facilitate skill acquisition and improvements in performance. Proc. Inst. Mech. Eng. Part P J. Sports Eng. Technol. **229**(2), 103–115 (2015)
31. Segerståhl, K., Oinas-Kukkonen, H.: Designing personal exercise monitoring employing multiple modes of delivery: implications from a qualitative study on heart rate monitoring. Designing for Healthy Living **80**, 203–213 (2011)
32. Tran, T.T., et al.: Comparison of physical capacities between nonselected and selected elite male competitive surfers for the National Junior Team. Int. J. Sports Physiol. Perform. **10**, 178–182 (2014)
33. Piwek, L., Joinson, A., Morvan, J.: The use of self-monitoring solutions amongst cyclists: an online survey and empirical study. Transp. Res. Part A Policy Pract. **77**, 126–136 (2015)
34. Bice, M.R., Ball, J.W., Mcclaran, S.: Techonology and physical activity motivation. Int. J. Sport Exerc. Psycology (2015)

35. Sheppard, J.M., et al.: Association between anthropometry and upper-body strength qualities with sprint paddling performance in competitive wave surfers. J. Strength Conditioning Res. **26**, 3345–3348 (2012)
36. Farley, O., Harris, N.K., Kilding, A.E.: Anaerobic and aerobic fitness profiling of competitive surfers. J. Strength Conditioning Res. **26**(8), 2243–2248 (2012) (Philadelphia)
37. Meir, R.A., Lowdon, B.J., Davie, A.J.: Heart rates and estimated energy expenditure during recreational surfing. Aust. J. Sci. Med. Sport **23**(3), 70–74 (1991)

Motivating Track and Field Athletes by Visualizing Training Drills and Records: Extraction and Visualization of Activities of Athletes from Blog Articles

Masakazu Sano, Hidetaka Masuda, Koichi Yamada and Tomohiro Fukuhara

Abstract The aim of this study is to support track and field athletes to keep their motivation. Our approach is based on collection, extraction, and visualization of athlete's activities by using blog articles. We collect blog articles written by track and field athletes. We extract menus, quantity, and the detail of training menus from these articles. We use the hidden Markov model (HMM) to extract these data. We then visualize the training and record data as graphs and tables. We provide athletes with various graphs and tables such as the distance graph.

Keywords Athlete's blog · Motivation · Information extraction · Hidden markov model

1 Introduction

Motivation is one of important factors for track and field athletes to keep their efforts and achieve their goals. There are two kinds of motivations: (1) intrinsic and (2) extrinsic. Intrinsic motivation focuses on one's internal motivation such as one's personal interests, and curiosities. Extrinsic motivation focuses on one's external or

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environmental influences such as rewards and compulsions and rival. According to studies of rivals in education, students who have rivals marked good records compared to others who don't have rivals [1]. In this study, we focus on the extrinsic motivation. We aim to motivate track and field athletes by providing them with information of person who is suitable for rival for them. On the Internet, there are many blog sites written by amateur track and field athletes. In these blog sites, they write their daily training menus and records in track meetings. By collecting these data, we consider that we can support athletes to keep their motivation by providing them with activities of other athletes who is suitable for rival for them. In this information, training menus, physical loads, quantities and distances of other similar athletes are included. We aim to provide athlete with rival information as visual graphs and tables which compares training menus and quantities between similar athletes.

Although this study is on-going, we confirmed that our method can extract menus and record by using the regular expression pattern matching; for extraction of menus, precision is 67.3 % and recall is 59.3 %. For extraction of record, precision is 80.9 % and recall is 73.9 % [2]. In this paper, we use HMM to extract menu. We do not need to prepare extraction pattern for each description that are different by athletes. Our method shows robustness for unknown description pattern of training menus because it doesn't rely on specific patterns but relies on statistical models that enabled us to process unknown description pattern. We argue an overview of the method and discuss our plan to evaluation of the method to support athletes to keep their motivation.

2 Motivation Support System

The aim of study is to develop a motivation support system. Figure 1 shows an overview of the system.

The system automatically collects blog articles written by amateur track and field athletes to analyze their activities. The user can recognize blog user as rivals when a one's record and records of blog users are in the similar level. The user can also refers to blog user's activity style if blog user's record are better than one's record. From such a thing, motivation support system expects to encourage a user to motivate to practice dairy training. The user also should write their daily training menus and records to notify other user. The system consists of following functions.

2.1 Extraction of Activities from Blog Articles

The system collects blog articles to extract activities of blog users by using the regular expression pattern matching and HMM.

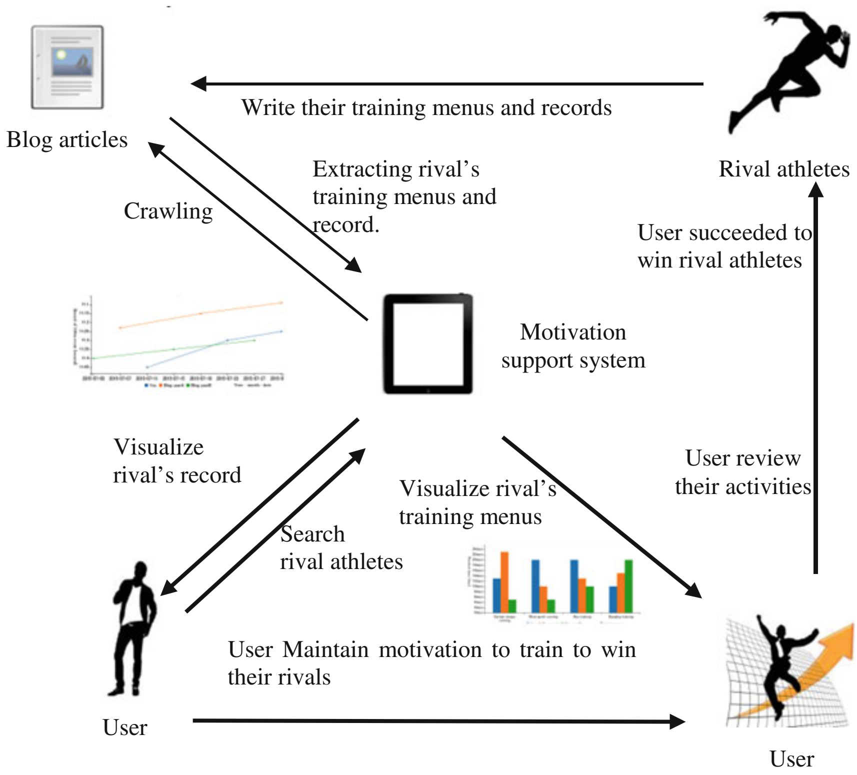

Fig. 1 Overview of motivation support system

2.2 *Recommendation of Blog Users*

The system recommends other athletes if records and activities style are similar to most of the user.

2.3 *Visualization of Activities*

We provide users with athlete activities visualization pattern in this graph. We recommend the user to use visualization graph of records and training at the same time.

Visualization of Records. Figure 2 shows a comparison graph of records between the user and blog user in 100 m track and field events.

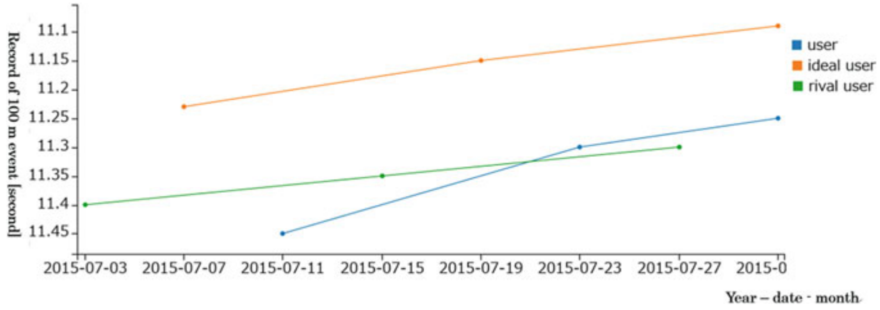

Fig. 2 Graph of record comparison in 100 m event

We assume *ideal user* is a person that users regard as an one's ideal athlete, *rival user* is a person that users regard as a one's rival, because ideal user has record as goal and rival user's record is not so much difference compared to one's record. Figure 2 shows the user's record is the most time consuming to run 100 meters on 2015 July eleventh. We assume the user regrets not to win competition and changes how to train in the 2015 July seventeenth. After that, the user succeeds in getting better records compared to rival users.

Visualization of Training. Figure 3 shows the comparison graph between a user and blog user in training.

Figure 3 shows the number of days that a user had a practice on each training compared to other athletes in a month. User can find which training is not sufficient compared to rivals by using this pattern graph. For example rival user got better records compared to user's record on 2015 July fifteen. User can find which training menus is not sufficient compared like that Abs training, chinning. We expect that users practice these training menus many times to win rival user on 2015 July twenty three. From the figure, visualization pattern motivates a user to train which has less frequency in the work than rivals if user are defeated by rivals in competition.

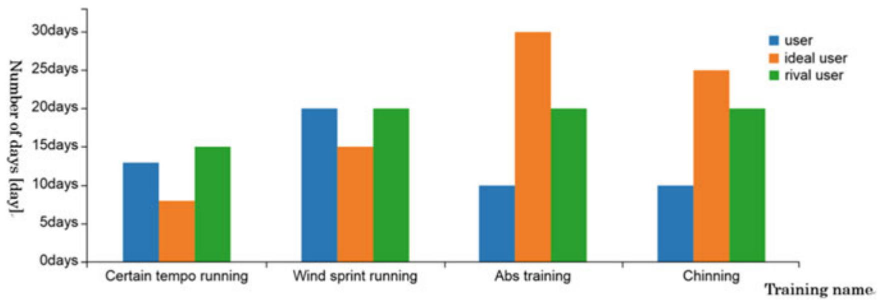

Fig. 3 Comparison day user worked each training compare to other athlete

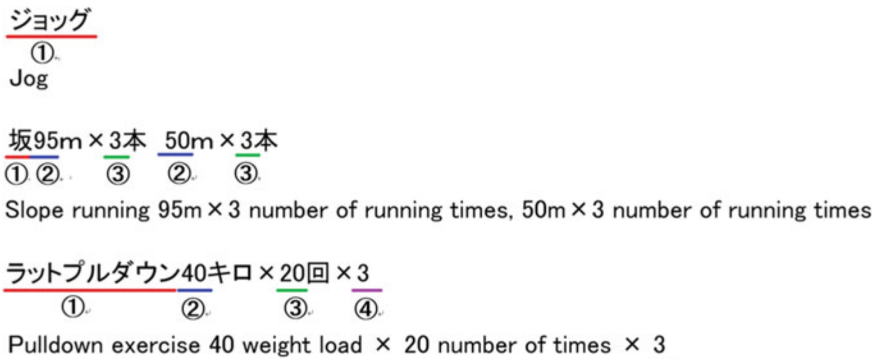

Fig. 4 A sample blog articles. *1* training name, *2* detail of training, *3* amount of training, *4* number of sets

3 The Blog Articles Written by Amateur Athletes

In this section, we overview blog articles written by amateur athletes. Articles written by athletes often contain descriptions about their daily training menus and records in competitions. Figure 4 shows a sample blog articles which contains for training menus in a day.

(1) *Training name* show the label of training that can be denoted differently by athletes. (2) *detail of training,* For example distance of running track, the load of training the body, (3) *amount of training* is the number of time to run certain distance and, train the body, (4) *Number of sets* is the number of time to work a training.

4 Extraction Method of Training Menus

We extract training menus appeared in blog articles. We extract training name, detail of training, amount of training, and number of sets. Figure 5 shows the overview of training menus extraction method.

We first extract training menus from blog articles by using the regular expression pattern matching. We can not only process by this method because there are many patterns of training menus. We prepare a training name dictionary. Training name dictionary is a list of training names which appears in many articles.

We have to extract training name, detail of training, amount of training, number of sets for visualization. We use hidden markov model (HMM) because dividing the sentence of training menus into the morpheme and tagging with named entity label such as training menus are similar to the part of speech tagging.

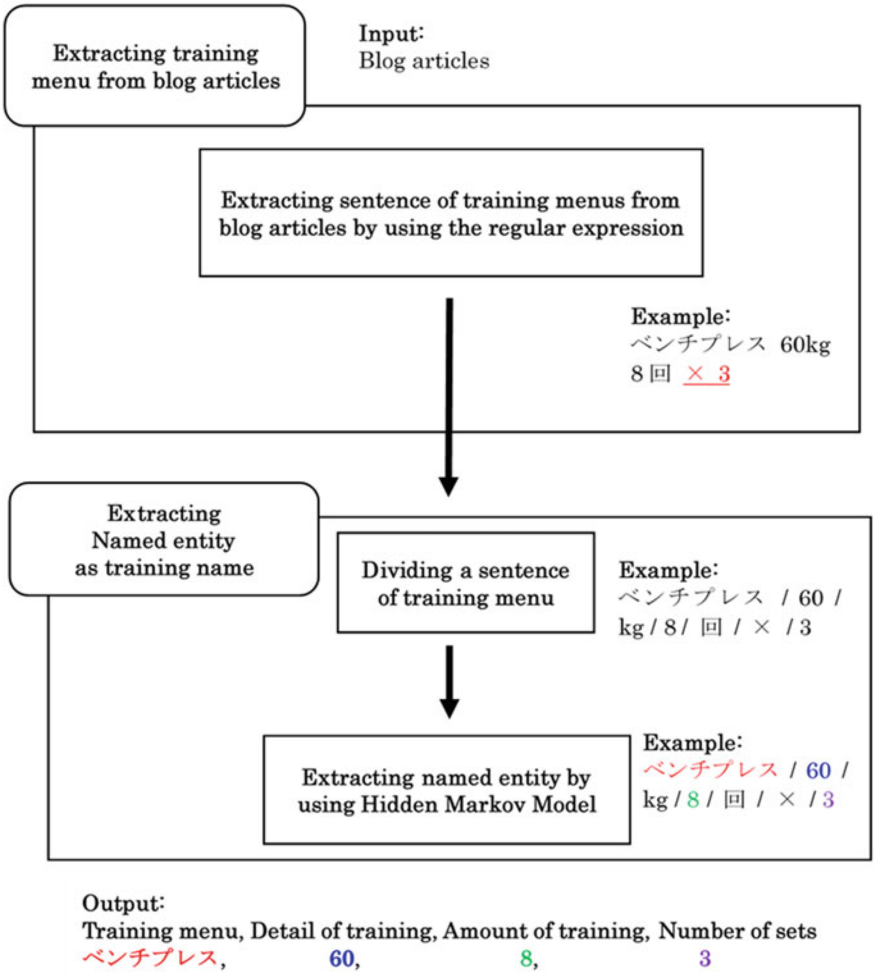

Fig. 5 Step to extract training menus

4.1 Extraction of Training Menus from Blog Sites

We provide the method which extracts training menus from blog articles.

Training Name Dictionary. We add words as training name to the dictionary part of speech tagger. We add 100 words to the dictionary.

The Regular Expression Pattern Matching. We use the regular expression pattern matching to extract training menus. Table 1 shows regular expression patterns.

Character "×" and "+" is the key to extract training menus.

Morphological Analysis by Using Training Name Dictionary. We can extract training menus from blog articles by using MeCab which is a Japanese

Table 1 Regular expression pattern

Training name
テンポ走 150 m × 5 (Certain tempo running 150 m × 5)
200 + 100 m

morphological analysis associated with the training name dictionary [3]. Because extraction results sometimes contains unnecessary words, the algorithm checks them before and behind morphemes which are suitable for training names.

4.2 Extraction of Named Entity by Using Machine Learning

We provide the method to extract training names, details of training, amount of training, Number of sets using HMM.

Dividing a Sentence of Training Menus. We divide a sentence into morpheme by using the POS tagger. We need to combine morphemes into one. For example "スプリントドリル" (sprint drills) was divide into "スプリント" (sprint) and "ドリル" (drill) by the POS tagger. We combine morphemes into one morpheme unless next morpheme is symbol or alphanumeric character.

Hidden Markov Model. HMM is a powerful statistical machine learning technique that is just beginning to gain use in information extraction tasks [3]. We need to estimate transition probability, emission probability, and tag each morphemes with label to obtain state transition sequence by using a Viterbi algorithm [4]. We learn training data set. Training data set is a set of morphemes tagged with label by hand.

The dataset contains morphemes edited by hand by using blog articles within between April 1st 2014 and 30th May 2015. We use 611 blog articles from 20 blog sites. Total number of training menus is 2171. Table 2 shows the label list.

Table 2 shows the list of labels. A label has a hierarchical relationship like the upper label is "Training name" and the lower is "Training name/Normal", "Training name/complex". Table 3 shows part of training data tagged with label at hand.

Table 3 shows a description of a training menus "SD 30 m × 3 50 m × 1 R5 ∼ 6分" which divide into morphemes. Each morphemes was tagged with labels correctly by hand. There are "R5 ∼ 6分" in the sentence. This phrase is what we don't need to extract. We tagged the morphemes divided from this phrase with specific labels such as "Remark".

We also tagged words with special labels such "Training name/complex" and "Detail/complex". Table 4 shows a list of specific labels.

The word tagged with specific label such as "Training name/complex" shows two or more named entity such as "スキップ" (skipping) and "200 m" in Table 4. However these words was divide into token by MeCab. These word also shows specific characters such as "→" and "+". Table 5 shows specific character list.

Table 2 Label list

Label	Description
Training name/Normal	Normal training name
Training name/Complex	The word of training menu contains two or more token as training name
Detail/Running distance	Distance of running track
Detail/Training load	Load weight of training the body
Detail/Remark	Time of training, Number of running steps
Detail/Complex	The word of menu contains two or more as token detail of training
Amount/Number of times to run	Number of time to run certain distance
Amount/Number of times to train	Number of time to train the body
Number of sets	Number of time to work a training

Table 3 Part of training data

Word	Label
SD	Training name/Normal
30	Detail/Running distance
M	Unit/meter
×	Specific symbol character/Amount
3	Amount/Number of times to run
Space character	Punctuation/From amount to detail
50	Detail/Running distance
m	Unit/Meter
×	Specific symbol character/Amount
1	Amount/Number of times to run
Space character	Punctuation/From amount to remark
R	Remark/Undefined word
5	Remark/Alphanumeric character
~	Remark/Symbol character
6	Remark/Alphanumeric character
分	Remark/Alphanumeric character

Table 4 List of specific label

Label	Word
Training name/complex	ｽｷｯﾌﾟ 100 m → ﾃﾝﾎﾟ走 200 m (Skipping 100 m → Certain Tempo Running 200 m)
Detail/complex	200 + 100 m

Table 5 List of specific character

Label	Word
Training name/complex	↑, → , からの, +
Detail/complex	+

We need to combine each morphemes into one if specific characters shown in Table 5 are located in front and behind morpheme which is a suitable for a named entity such as “Training name”, “Detail”.

We estimate parameters such as transition probability for extracting named entity such as “Training name” by using training data [5]. However we can not obtain the state transition sequence without probability smoothing process because sometimes there are not transitions between all states, we have an opportunity to process unknown words so that probability will become “0”. We need a linear interpolation process as smoothing process [5].

5 Experiment

We had an experiment of tagging morphemes divided sentence of training menus extracted from blog articles. We prepare training data, test data set, correct data set. We do experiment is 5 cross validation to calculate precision and recall.

Formula of recall, precision, are following:

$$Precision = \frac{|\{tagged\ labels\} \cap \{relevent\ labels\}|}{|\{tagged\ labels\}|} \quad (1)$$

$$Recall = \frac{|\{tagged\ labels\} \cap \{relevent\ labels\}|}{|\{relevent\ labels\}|} \quad (2)$$

We use set of morphemes tagged with labels by hand as training data. We checked whether the morpheme in test data was tagged with same label in correct data. We need a linear interpolation when we extract named entities as training names by using HMM. We do interpolation coefficient value as 0.05.

Table 6 shows the results of the five cross validation tests of tagging morphemes with labels by using test data set. The result shows that average, variance precision, recall to tag morphemes in test data set with respective label.

From experiment result, we found both morphemes could be tagged and could not be tagged with relevant label.

Table 7 shows a list of morpheme tagged with relevant label.

The word “10” in the sentence of “バック懸垂 10回 × 2” was tagged with “Amount/Number of times to train” as label correctly because transition probability from “Amount/Number of time” as state to “Unit/Number of time” as state is very high. The morpheme “回” means unit for number of times to train.

Table 6 Precision, recall for the 5 cross validation tests to tag morphemes with label

Label	Precision M (Variance)	Recall M (Variance)
Training name/Normal	0.94 (0.125×10^{-3})	0.95 (0.634×10^{-4})
Training name/Complex	0.90 (0.599×10^{-2})	0.77 (0.343×10^{-2})
Detail/Running distance	0.93 (0.186×10^{-3})	0.95 (0.190×10^{-3})
Detail/Training load	0.92 (0.185×10^{-2})	0.96 (0.348×10^{-3})
Detail/Complex	0.96 (0.800×10^{-2})	0.62 (0.220×10^{-1})
Detail/Remark	0.86 (0.535×10^{-2})	0.92 (0.667×10^{-2})
Amount/Number of times to run	0.92 (0.400×10^{-3})	0.94 (0.186×10^{-3})
Amount/Number of times to train	0.93 (0.355×10^{-3})	0.91 (0.847×10^{-3})
Number of sets	0.93 (0.779×10^{-4})	0.94 (0.276×10^{-3})

Table 7 List of morpheme could be tagged with relevant label

Training name (Japanese)	Training name (English)
バック懸垂10回 × 2	Back chinning exercises 10 time × 2
150 m × 3 快調走　R7分(18秒28)	150 m × 3 wind sprint R7min(18s28)

The unnecessary phrase “R7分(18秒28)” included in the sentence of “150 m 3 快調走　R7分(18秒28)” was not tagged with important label such as training name because we tagged unnecessary morpheme with specific label like that “Remark/”

Table 8 shows list of morpheme could not be tagged with relevant label.

The word “ハイニースキップ 30 m → スキップ 70 m” in the sentence of “ハイニースキップ 30 m → スキップ 70 m × 5” will be tagged with “Training name/Complex” as label correctly. However we tagged the word with “Training name/Normal” as

Table 8 List of morpheme tagged with relevant label

Training name (Japanese)	Training name (English)
ハイニースキップ 30 m → スキップ 70 m × 5	High knees skipping 30 m → skips exercise 70 m × 5
懸垂 40	Chinning exercises 40
緩坂上りワンハンド・ダッシュ 30 m × 3	Loose hill dash training 30 m × 3

label by mistake because the word has not been included in Training data set so that, Value of emission probability from all states is “0”. The extraction system tend to tag with “Training name/Normal” as state because the highest transition probability from initial state is this state.

6 Discussion

We aim to motivate track and field athletes by providing them information of person who is suitable for rival for them. We collected about 20 amateur athlete’s blog sites from the Internet by hand for extracting their activities. However it was difficult to extract their activities by using the regular expression pattern matching algorithm because description pattern of training menus written in blog sites is different by each person. In this paper, we use HMM as statistical model to estimate the probability of a set of observations based on the sequence of hidden state transitions.

Extraction experiment results shows both precision and recall were 90 % or more.

We have finished to suggest methods to visualize athlete’s activities for encourage to users to maintain motivation.

We will implements visualization of their activities, and have an experiment to maintain motivation by using our motivation support systems.

7 Conclusion

In this paper, we suggest motivation support system to encourage athletics athletes to maintain motivation.

We had an experiment to check to extract training menus from athlete’s properly.

The average precisions, recall is 0.9 above except “Training name/Complex” and “Detail/Complex”. We will implements motivation support system and visualize training menus for experiment to encourage athletics athletes to maintain motivation.

References

1. Ota, N.: Rival significance in education—analyzing rival recognition. Psychology. Bull. Univ. Nagoya. **46**, 309–310 (1999) Japan
2. Sano, M., Fukuhara, T., Masuda, H., Yamada, K.: Extraction of athlete’s activities from blog articles. In: The 29th Annual Conference of the Japanese Society for Artificial Intelligence, no. 29, pp. 1–4 (2015) (Japan)

3. Sermore, K., McCallum, A., Rosenfeld, R.: Learning Hidden Markov Model Structure for Information Extraction. AAAI Technical Report, WS-99–11 (1999)
4. Kita, K., Tsujii, J.: Statistical models for natural language processing, University of Tokyo Press. Comput. Linguist. **4**, 101–125 (2008) (Japan)
5. Ageishi, R., Miura, T.: Part of speech tagging for english to extract named entity. DEWS **E7-6**, 1–6 (2008) (Japan)

Effect of the Functional Dynamic Warm-up on Speed, Power and Core Muscle Endurance for Adolescent

Ting Liao, Yin Yu and Bing Wang

Abstract There is seldom practical research on the science and effectiveness of warm-up in the area of our youth physical education. The purpose of this study was to examine the effects of a twelve-weeks functional dynamic warm-up (FDWU) intervention on the improvement of speed, power and core muscle endurance in the middle school students. The results of data indicated that applying FDWU in youth PF teaching area, instead of applying traditional regular warm-up, can significantly increase students' skill and physical performance as well as prevent sports injury to some extent. Owing to its fresh and interesting style, rich and varied content, progressive difficulty level, scientific and effective training methods and flexible and convenient processing, FDWU could be inserted into any youth PE system as main course assistant complement.

Keywords Functional dynamic warm-up · Adolescent · Speed · Power · Core muscle endurance

1 Introduction

Traditional warm-up exercises are mainly aerobic low-intensity activity consisting of jogging, in-sit free-standing exercise and static stretching. These exercises have been questioned by scholars at home and abroad in recent years. Researches show that traditional warm-up exercises have negative influence on speed and explosive

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power of teenagers [1]. The weak effect to injury prevention cannot meet the requirements of more exercises and less damage in physical education of middle school. For teenagers, the static and dynamic postures (including cacoethic sitting, walking, running and jumping) will put inappropriate pressure, torque or tension on spine, lower limb muscles, ligaments and cartilage, causing athletic injury [2]. Thereinto, low back pain, as one of the most common diseases of modern civilization, is widely popular in teenagers. Low back pain persecutes 18–33 % of teenagers, where 80 % will suffer low back pain in adulthood. The pain is mainly caused by body core area and spine stability deficiency because of weak endurance of trunk extensor muscles.

Traditional warm-up exercises have limitation in promoting the anaerobic capacity and preventing injury [3]. Based on this, functional dynamic warm-up mode is proposed by international experts in physical training, and introduced to the field of physical education. Functional dynamic warm-up mode consists of a series of incremental dynamic movements and stretching exercises including squat, jump, stretch, balance, stability and postural control at low, middle and high levels. With this mode, the body temperature of the core area is rapidly improved to arouse the excitability of motor units and the neuromuscular system, thus enlarging perception ability of muscle system and active motion range of joints. Research shows that functional dynamic warm-up mode can start PAP (Postactivation potentiation) by emphasizing the function of the nervous system, thus efficiently creating production environment of optimal speed and explosive power. In unsteady state of this mode, the actions are completed by effective coordination of trunk core muscle [4]. The above researches prove that dynamic stretch has positive influence on standing long jump, vertical jump and sensitivity of adults. In addition, functional dynamic warm-up can promote speed, anaerobic exercise performance and trunk muscle endurance of young athletes. In physical class of middle school, functional dynamic warm-up exercises can be used to promote physical health of teenagers. After that, the work discusses the whole influence to speed, explosive power and core area muscle endurance.

Functional training is a purposeful and new physical training idea according with human anatomy and physiology characteristics. It is applied to maintain sustainable development of human body. Functional dynamic warm-up exercises are designed according to the basic principle of the comprehensive development of adolescent physical health. Correct body postures are established to complete purposeful exercises [5]. The consistency of training adaptation and purpose is reflected by training requirement analysis and action simulation.

Based on core idea and principle, the work attempts to establish a functional dynamic warm-up scheme with simple operation and short time consumption for students of junior middle school in China. This scheme can gradually improve physical health without equipments. In physical class of middle school, functional dynamic warm-up experiments for 12 weeks are used to discuss the application effect in physical education field of teenagers. Therefore, it is assumed that functional dynamic warm-up exercises can effectively improve speed, explosive power and core area muscle endurance of teenagers in China.

2 Research Object and Method

2.1 Subject

Experimental object consists of 110 grade two students (62 boys and 48 girls) of Guanshan junior middle school, Wuhan City, Hubei Province. Thereinto, experimental group consists of 32 boys and 23 girls; control group of 30 boys and 25 girls. The whole experimental object has no professional sports experience, physical or mental disease. For the experimental object, the physical examination is normal; there is no lack of the basic sports experience caused by major trunk injury or surgery in the last year; there is no injury pain in the last month. The experimental object regularly participates in the physical education activities every week. There is no any extracurricular sports activity. Before experiment, the potential risks are informed to test object and the parents with written form. After that, formal consent is signed.

The research is supported by Culture and Sports Bureau of Hongshan District, Wuhan City, Hubei Province; The School Committee of Guanshan Middle School, Wuhan City, Hubei Province; Exercise Collaborative Innovation Center for Intervention and Health Promoting of Hubei Province.

2.2 Experimental Method

Experimental Design. The research applies two factor composite experiment design—repeatedly measuring three factors by 2 × 2. Thereinto, experimental treatment levels (functional dynamic and traditional warm-up exercises) are between-subjects variables; measurement time levels (before and after measurement) are within-subject variables. The latter are repeated measurement factors. Dependent variables designed are speed, explosive power and core area muscle endurance. Experimental objective is to validate the influence of 12-week functional dynamic warm-up experiment intervention (6–10 activities for 10–15 min) to physical quality promotion of teenagers in physical class of junior middle school (3 classes every week; 45 min every class). Before experimental intervention, students of experiment and control groups receive the tests of speed, explosive power and core area muscle endurance after traditional warm-up exercises.

Experiment group uses functional dynamic warm-up exercises. Control group uses traditional warm-up exercises (jogging for 2 × 400 m; free-standing exercise for 6 section of 4 × 8 beat; static stretch for 4 movements). Except for warm-up segment, the two groups complete the contents of sports teaching in junior middle school according to the syllabus. After experimental intervention, experiment group complete functional dynamic warm-up exercises to receive the same test; control group complete traditional warm-up exercises to receive the test. The test sequences are consistent before and after the experiment.

Functional Dynamic Warm-Up Exercise Scheme. The work formulates functional dynamic warm-up exercises suitable for this research by consulting relative data and experts in physical training and youth sports education field. After that, the work designs functional dynamic warm-up experiment continuum for teenagers (see Fig. 1). In the experiment, the whole object completes the activities step by step under the guidance of me and a teaching assistant. Experiment field is open and anti-slip flat land 10 × 20 m.

Test Methods of Core Area Muscle Endurance and Explosive Power. The work tests the influence of functional dynamic warm-up exercises to physical quality of teenagers by three quality indexes including speed, explosive and core area muscle endurance.

Speed and Explosive Power Test. The research tests speed by selecting 50 m run reflecting speed quality and nervous system flexibility development. In addition, the work tests explosive power quality development by selecting standing long jump (reflecting explosive force of the lower limbs and body coordination ability development) and sitting type solid ball throw (reflecting explosive force of the upper limbs).

Core Area Muscle Endurance Test. Designed by Rehabilitation Expert McGill, the test is mainly used to evaluate isometric endurance of core muscle group in flexion state of vertical plane (on both sides) and frontal plane. The whole test consists of FLEX, EXT, LATl and LATr. Researches show that this method has

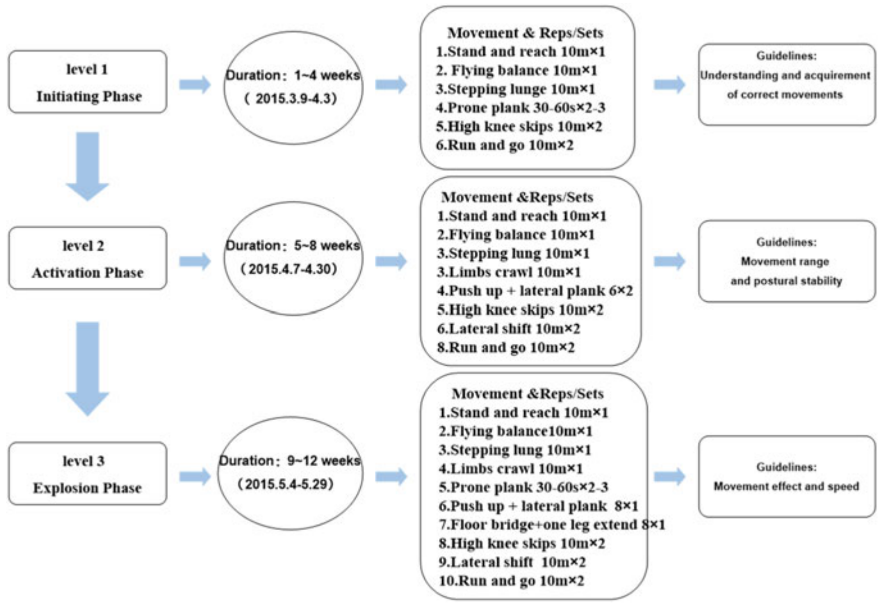

Fig. 1 Youth's functional dynamic warm-up experiment continuum

reliability and validity. Stopwatch is used to record the time of maintaining the standard test posture.

Data Analysis and Process. Basic situation of experimental object is presented by descriptive statistics (average ± standard deviation). Independent-samples t test method of SPSS17.0 is applied to test relative index change of experiment and control groups before and after experiment. Significant Level $P = 0.05$.

3 Research Result and Analysis

3.1 Research Result

Before experimental intervention, experimental objects are conducted with relative index test to ensure unremarkable difference of body shape characteristics, core area muscle endurance and explosive powers between experiment and control groups. Result shows that two groups have no obvious difference ($P > 0.05$), and grouping tends to be reasonable (see Table 1).

Research result indicates that indexes of two groups have changed after 12-week functional dynamic warm-up intervention. Table 2 shows that the growth level of experiment group in speed, explosive power and core area muscle endurance is higher than that of control group. There are significant differences before and after experiment.

After standing long jump test, explosive power of the control group negatively increases, with unremarkable characteristics. This phenomenon accords with relative research on negative influence of traditional warm-up exercises to explosive power quality to a certain extent (Figs. 2 and 3).

3.2 Analysis and Discussion

Influence of Functional Dynamic Warm-Up to Speed and Explosive Power Quality. Adolescence is an important period of developing movement speed and explosive power quality. Determining optimal training stages of teenagers with different body qualities is important to athletic ability and health development. Performance of speed and explosive requires effective work of muscle and hear lung system. It also requires excitation, coordination and control of neuromuscular system. According to modern concept of physical function training, good speed and explosive quality are determined by collaboration of multiple qualities including strength, sensitivity, flexibility, coordination and balance. Speed and explosive power are fully developed to avoid youth sports injury based on stable body function and optimal joint range of motion.

Table 1 The protest fundamental feature of body shape of experimental group and control group (mean ± SD)

Group	Age (y)	Height (cm)	Weight (kg)	Core muscle endurance (s)				Speed (s)	Power (m)	
				FLEX	EXT	LATl	LATr	50R	LJ	SMBT
Experimental group	13.22 ± 2.34	166.21 ± 16.82	58.51 ± 3.02	13.52 ± 9.24	12.72 ± 8.06	10.37 ± 7.57	12.42 ± 8.22	8.2 ± 1.11	1.65 ± 0.52	2.17 ± 0.97
Control group	13.71 ± 2.68	165.89 ± 17.46	57.67 ± 19.42	13.01 ± 7.56	13.14 ± 9.78	11.24 ± 9.40	11.97 ± 8.85	8.18 ± 1.23	1.64 ± 0.57	2.01 ± 0.88
P 値	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Table 2 The comparison of post-test result of core muscle endurance, speed and power between experimental group and control group

	Test	Experimental group		Differentials	Control group		Differentials
		Pro-test	Post-test		Pro-test	Post-test	
Core muscle endurance	FLEX (s)	13.52 ± 9.24	32.23 ± 6.81	18.71**	13.01 ± 7.56	14.65 ± 7.56	1.64
	EXT (s)	12.72 ± 8.06	26.07 ± 6.88	13.35**	13.14 ± 9.78	14.26 ± 9.18	1.12
	LATl (s)	10.37 ± 7.57	26.97 ± 8.31	16.6**	11.24 ± 9.40	12.26 ± 9.61	1.02
	LATr (s)	12.42 ± 8.22	27.17 ± 9.14	14.75**	11.97 ± 8.85	12.91 ± 7.63	0.94
Speed and power	50R (s)	8.2 ± 1.11	7.35 ± 1.09	0.85*	8.18 ± 1.23	8.19 ± 1.88	0.01
	LJ (m)	1.65 ± 0.52	1.83 ± 0.49	0.18**	1.64 ± 0.57	1.61 ± 0.66	−0.03
	SMBT (m)	2.17 ± 0.97	2.64 ± 1.22	0.5**	2.01 ± 0.88	2.11 ± 0.95	0.1

n1 = n2 = 55; $*P < 0.05$ $**P < 0.01$

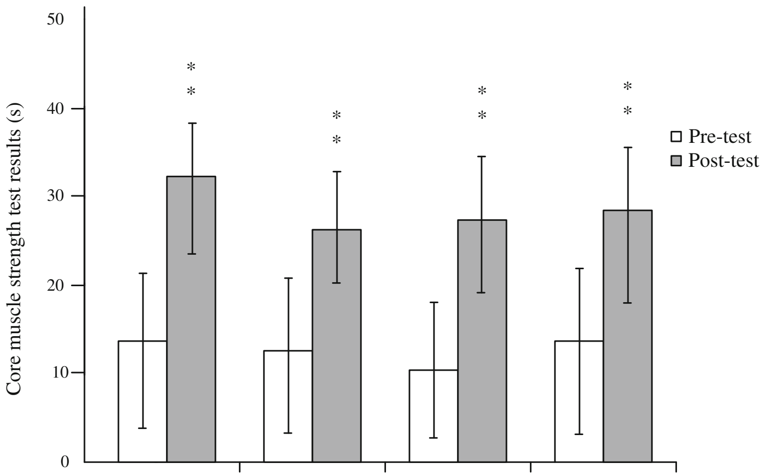

Fig. 2 The comparison of core muscle strength results of experimental group between pre-test and post-test

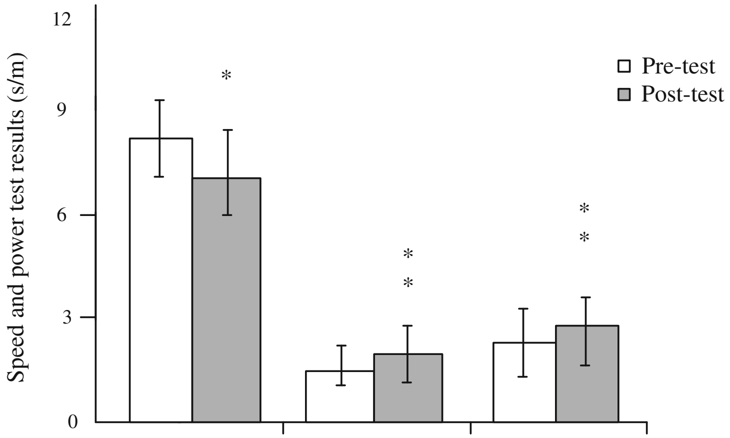

Fig. 3 The comparison of speed and power test results of experimental group between pre-test and post-test

Experimental research shows that functional dynamic warm-up exercise is more efficient to promote development of speed and explosive power than traditional warm-up mode. In functional dynamic warm-up process, relative muscles and joints continue active shrinkage control to complete predetermined activities after gradually Stretching to a larger range. Traditional static stretch aims at stretching and relaxing the muscle system. Functional dynamic warm-up exercise activates the neuromuscular system to actively complete stretch, balance and stability exercises. Functional dynamic warm-up mode emphasizes correct dynamic body postures.

Therefore, warm-up mode based on activities can be used to improve body postures, muscular strength and perception ability of kinetic system, thus enlarging joint motion range.

Functional dynamic warm-up exercise is designed according to physical and psychological development characteristics of teenagers. It consists of start, activation and burst stages (see Fig. 4). In start stage, multiple dynamic stretch and balance actions are used to release students from mental state and increase participation of physical exercise system, starting physical education. The simple and interesting actions require participation of small muscle groups in multiple positions. In activation stage, basic physical activities including squat, run and jump are improved to motivate neuromuscular system. Action design emphasizes integration of movement track and functional action in multiple directions, preparing for physical education curriculum. Burst stage is the most challenging practice stage of functional dynamic warm-up mode. It has the functions of preparation and improvement. Exercises on basic function motion technology lay the foundation for learning content of sports body postures for lateral dribbling in basketball learning. Spine stability exercise can strengthen transfer efficiency of body movement chain and output effect of functional power [6]. It also provides good body preparation for physical emergency exercise mode caused by games or competitions in physical education curriculum of teenagers, thus preventing sports injury. Compared with traditional aerobic warm-up exercise, functional dynamic warm-up exercise provides active, incentive and diversified activity patterns, thus liberating minds and bodies of students in physical class. Meanwhile, body activity systems are fully prepared for main exercise content.

Influence of Functional Dynamic Warm-Up to Core Area Muscle Endurance. Avoiding damage by addition of exercise amount is an important problem to be solved in physical education of middle school. The work proves the influence of functional dynamic warm-up exercise to the improvement of core area muscle endurance quality of teenagers. Core area consists of axial bone and attached

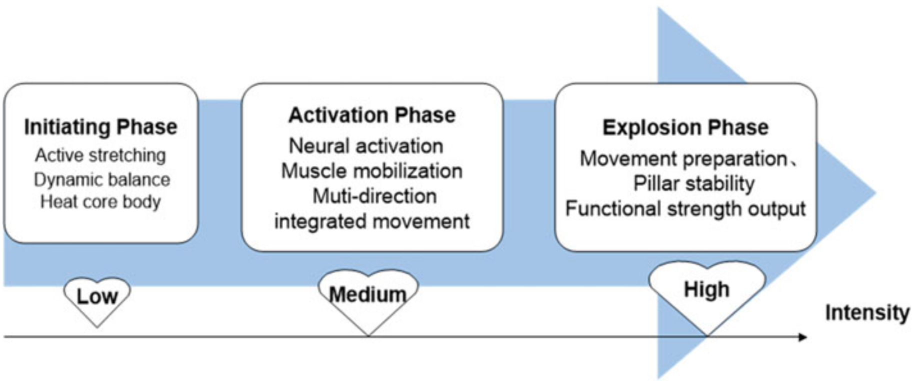

Fig. 4 Youth's functional dynamic warm-up phase continuum

soft tissue. The chief muscle group includes rectus abdominis, external oblique and trunk extensor. The endurance performance of extensor muscles in core area is directly related to the incidence of low back pain. As the main extensor of trunk, erector spine is in charge of stretching the spine [7]. It is integrated with flexor muscles to form rivalry, thus eccentrically braking body flexion movements. Research shows that poor performance of core area extensor endurance foreshadows 3 times incidence of low back pain [8]. Degeneration of lower lumbar function in adolescence is seemed as blasting fuse of recurrent low back pain in adult stage. To avoid imbalance of muscle development, coordinated development of the whole muscles in core area is superior to development of extensor muscles. The stability of trunk is effectively strengthened to increase endurance of the lower lumbar to the pressure in dynamic body activity, thus improving sports performance and preventing injury.

Action design of functional dynamic warm-up emphasizes interaction of basic action preparation strategy, dynamic core stability, posture control and functional strength training characteristics (see Fig. 5). The effective control of the human body to the action is achieved by proprioception, sensorimotor integration and muscle synergy effect. Dynamic balance and stability exercise of body posture are used to promote the input of proprioception and perception ability of muscle motor system. Excitability of neuromuscular system is rapidly improved to synchronously strengthen dynamic balance, posture control ability and functional strength performance [9]. In practice process, students should reduce the movement of lumbar spine and pelvis. For students, center of body weight achieves stability by constant self-adjustment in dynamic imbalance state. Functional dynamic warm-up exercise is integrated into physical education curriculum of teenagers. Students learn basic function movement patterns to improve body quality, dynamic movement and control abilities [10–14]. The advantages are reflected in limited space and small equipment [15–17]. Students can randomly assemble training schemes seamlessly connected with main learning content. By short-term control experiment research, the work proves that functional dynamic warm-up exercise is effective and feasible to promote youth body quality in middle school.

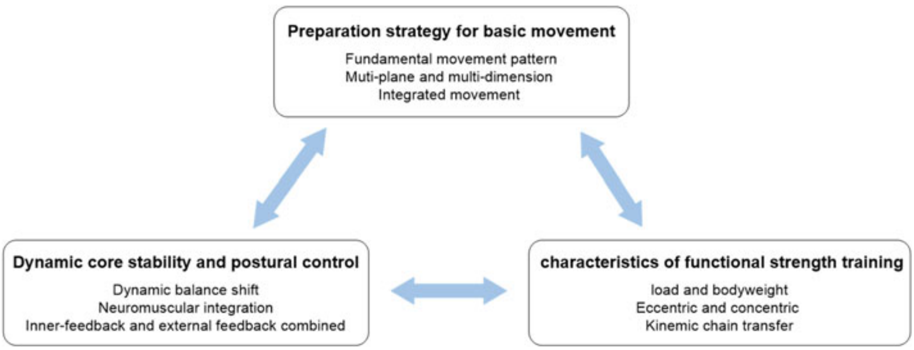

Fig. 5 Design strategies of youth's functional dynamic warm-up

Functional dynamic warm-up exercise is designed according to body function development of teenagers. With new form, abundant content and simple operation, it can be introduced into any physical education curriculum system of middle school as auxiliary teaching content. The teaching effect of force and skill is promoted to prevent sports injury to a certain extent.

4 Conclusions and Suggestions

1. In physical education class, functional dynamic warm-up exercise is used to substitute traditional exercise, thus effectively improving speed, explosive force and core area muscle endurance of teenagers.
2. Based on modern physical function training concept, functional dynamic warm-up scheme is established for physical education of middle school. Taking incremental sequence and design strategy as practice evidence, functional dynamic warm-up scheme aims at promoting harmonious development of the youth's body function.
3. Experimental researches of large samples during longer time are conducted to investigate the universality of the scheme.

References

1. National Institute of Child Health and Development: Frequency and intensity of activity of third-grade children in physical education. Arch. Pediatr. Adolesc. Med. **157**, 185–190 (2003)
2. Cornwell, A., Nelson, A., Heise, G., Sidaway, B.: Acute effects of passive muscle stretching on vertical jump performance. J. Hum. Mov. Stud. **40**, 307–324 (2001)
3. Yamaguchi, T., Ishii, K.: Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. J Strength Cond Res. **19**, 677–683 (2005)
4. Thacker, S., Gilchrist, J., Stroup, D., Kimsey, C.: The impact of stretching on sports injury risk: asystematic review of theliterature. Med. Sci. Sports Exerc. **36**, 371–378 (2004)
5. Calvo-Munoz, I., Gomez-Conesa, A., Sanchez-Meca, J.: Prevalence of low back pain in children and adolescents: a metaanalysis. BMC Pediatr. **13**, 1–12 (2013)
6. Auvinen, J., Tammelin, T., Taimela, S., Zitting, P., Karppinen, J.: Associations of physical activity and inactivity with low back pain in adolescents. Scand. J. Med. Sci. Sports **18**, 188–194 (2008)
7. Faigenbaum, A., Bellucci, M., Bernieri, A., Bakker, B., Hoorens, K.: Effects of different warm-up protocols on fitness performance in children. J. Strength Conditioning Res. **19**, 376–381 (2005)
8. Faigenbaum, A., Mcfarland Jr., J.E.: Guidelines for implementing a dynamic warm-up for physical education. J Phys. Educ. Recreation Dance **78**, 25–28 (2007)
9. Robbins, D.W.: Postactivation potentiation and its practical application: a brief review. J. Strength Conditioning **19**, 453–458 (2005)
10. McMillian, D.J., Moore, J.H., Hatler, B.S., Taylor, D.C.: Dynamic vs. static-stretching warm up: the effect on power and agility performance. J. Strength Conditioning Res **3**, 492–499 (2006)

11. Siatras, T., Papadopoulos, G., Mameletzi, D., Gerodimos, V., Kellis, S.: Static and dynamic acute stretching effect on gymnasts' speed in vaulting. Pediatr. Exerc. Sci. **15**, 383–391 (2003)
12. Faigenbaum, A.D., Kang, J., Mcfarland, J., et al.: Acute effects of different warm-up protocols on anaerobic performance in teenage athletes. Pediatr. Exerc. Sci. **17**, 64–75 (2006)
13. Bird, S.P., Stuart, W.: Integrating balance and postural stability exercises into the functional warm-up for youth athletes. Strength Conditioning J. **34**, 73–79 (2012)
14. McGill, S.M., Childs, A., Liebenson, C.: Endurance time for low back stabilization exercise: clinical targets for testing and training from a normal database. Arch. Phys. Med. Rehabil. **80**, 941–944 (1999)
15. Behm, DG, Bradbury, EE, Haynes, AT, Hodder, JN, Leonard, AM, an dPaddock, R. Flexibility is not related to stretch-induced deficits in force or power. J Sports Sci Med.5: 33–42 (2006)
16. Akuthota, V., Nadler, S.F.: Core strengthening. Arch. Phys. Med. Rehabil. **85**, 86–92 (2004)
17. Feldman, D., Shrier, I., Rossignal, M., Abenhaim, L.: Risk factors for the development of low back pain in adolescence. Am J Epidemiol. **154**, 30–36 (2001)

Empirical Analysis of Japanese Football Games Using Structural Equation Modeling

Michiko Miyamoto, Yuji Kaneki and Yuta Misumi

Abstract This paper presents a framework and an empirical result for two football games played by Japanese professional football teams, focusing on their offence. By using ball possession data, this study analyses the performance of midfielders' and forwards' tasks, such as assists, breaking down, passthrough, and traps to determine associations among selected strength and performance variables which lead to scoring. The structural equation modeling (SEM) was used to test the framework.

Keywords Football games · Ball positioning data · Structural equation modeling

1 Introduction

Football is one of the most popular sports in the world. It is also listed as the second most popular professional sport in Japan, next to baseball as shown in Fig. 1. Japanese football has more than 100 years of history since British naval officers brought the game in 1873 [1]. The Japan Football Association was founded in 1921 with only four teams; currently the number has risen to over 6000. The J1 League is the top division of Japan Professional Football League in Japan, and J2 League is represented as the second tier. 18 clubs contest a two-stage regular season in addition to Championship. Japan has qualified for every World Cup since they made their debut in France in 1998, along the way; the J-League has produced world class players with the quality to play at any team in the world.

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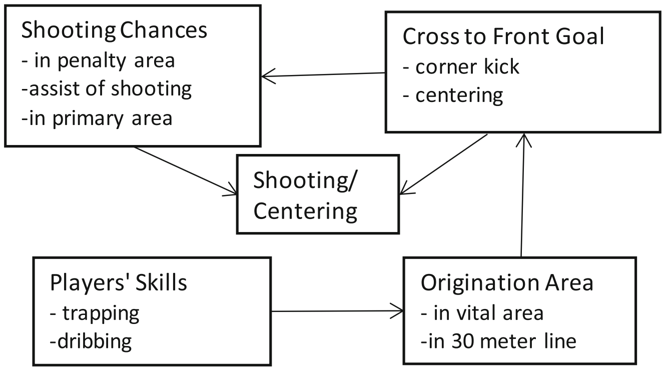

Fig. 1 Research model

Winning every game is the most important matter for any professional sport teams. Advances in technologies available for on-field sports performance have increased immensely in recent years. The use of motion analysis technology allows for individual monitoring and gives useful feedback for coaches and fitness staff [2]. This paper presents a framework and an empirical result for two football games played by J1 League teams, focusing on their offense, using ball possession data.

2 Research Background

In football, each player is required to exhibit accuracy of skill and quick judgment within a limited space while collaborating with other players to achieve harmonized team play [3, 4]. Although many notational and/or statistical analyses of football matches have been presented, few previous analyses of a prolonged winning streak by a single side have been reported [5].

In early study, Reep and Benjamin [6] listed factors affecting the likelihood of a successful pass in association football: (1) the positions of the players between whom the pass is attempted and the defending players who try to intercept; (2) the relative skills of the players and the effectiveness and confidence with which those skills are applied at this particular stage of the game. This research seems to have shaped the tactics of British football [7], and the results have been reconfirmed by analyses of different FIFA World Cup tournaments by several different research groups.

Most coaches have been affected, to a greater or lesser extent, by the tactics referred to as the “long-ball game” or “direct play”, which was a tactic employed as a consequence of this research. The ability to retain possession of the ball for prolonged periods of time has been linked to success in football [8]. Jones et al. [9] investigate the accuracy of this assertion by comparing 24 matches involving successful and unsuccessful English premier league teams within the 2001–2002 season. It was concluded that within elite English football possession is related to successful performance but it is likely this is down to differences in individual player's skill levels rather than specific team strategy.

Using game performance analysis framework, Dawson et al. [5] compared match statistics of Brisbane Lions Football Club in Australian Football League; averaged over the first nine regular season games and the last 13 regular season games with the mean match statistics of the other seven sides that made finals, as well as the mean match statistics of the other 15 teams in the League combined. Their offensive statistics include possessions per goal scored, total number of points scored, number of individual goal scores in each game, number of entries into the forward 50-m zone, number of unbroken chains of possession, and how the goals were scored. Their defensive statistics include the respective number of tackles, bumps, spoils shepherds (blocks or screens), and smothers of opposition kicks.

Based on extensive literature review on performance analysis (PA), Mackenzie and Cushion [10] noted that the substantial body of PA research undertaken in relation to football, and focused on key performance indicators such as possession and passing patterns prior to goals being scored in attempts to predict successful future performance.

Some investigated technical and physical comparisons across different leagues [11–13] and statistical analyses of goal scoring probabilities [14–16].

Using data collecting from GPS devices fitted to the upper back of each player using an elastic harness, Wisbey et al. [17] analyze movements of AFL footballers (n = 179) from 8 of the 16 AFL clubs during the 2008 AFL season, compared to 52 footballers in 2005, 85 in 2006 and 203 in 2007. They found that midfielders covered more distance, had higher exertion levels, and more running at higher velocities than fixed position players.

As far as football games analyses in Japan, characteristics of attach-related game aspects within three football leagues (Japanese University Football League (JUL), Japanese professional J-League (JL) and UEFA Champions League (CL)) were analyzed and found no significant differences were observed in frequency of attacks, shots, and goals [18]. In soccer, scoring goals is the ultimate determinant of success and has consequently received considerable attention in notation research [19]. The most popular performance indicator in soccer is possession of the ball [20–27]. One of the richest findings in the discipline is the correlation between the ability to retain possession of the ball for prolonged periods of time and success [19, 20, 28].

3 Research Model and Hypotheses

This paper empirically investigates factors affecting shooting, which eventually lead to score goals. Those factors include players' skills (trapping and dribbling) in origination area (in vital area, in 30 m line), cross to front goal (corner kick, centering), and shoot chances (in penalty area, assist of shooting, in primary area) as shown in Fig. 1. More specifically, we will investigate the following five hypotheses regarding factors affecting shooting;

- H1: Players' Skills will affect Origination Area
- H2: Origination area will affect Cross to Front Goal
- H3: Cross to Front Goal will affect Shooting Chances
- H4: Cross to Front Goal will affect Shooting or Centering
- H5: Shooting Chances will affect Shooting.

For estimating a fit between factors, advanced quantitative techniques of structural equation modeling (SEM) [29] have been employed. SEM has been established as an analytical tool, leading to hundreds of published applications per year. Overviews of the state of the method can be found in Cudeck et al. [30], Jöreskog [31], Mueller [32], and Yuan and Bentler [33]. Based on these results of analyses, we will measure how such factors, i.e., shoot chance, cross front goals, players' skills, and in origination area, affect shooting.

In structural equation modeling, we consider the causalities among all variables, especially between the result and the latent variables. Latent variable enables us to find many compiled observed variables at the same time based on the notion of structure. This works for generating and verifying hypotheses to find factors and causalities.

4 Data

Ball possession data in this study was provided by Data Stadium Inc., Japan's leading sports information provider. Descriptive statistics of variables for two football games from the J1 League, First Stage, 2nd Section 2015 are shown in Table 1. More specifically, these games are Shonan Bellmare versus Kashima Antlers, and Shonan Bellmare versus Matsumoto Yamaga. Shonan Bellmare won both games. We focus on their offences1; i.e., midfielders and forwards. 3658 ball possessions are identified for two games.

Shonan Bellmare and Kashima Antlers are members of the J1 league for some time, while it was the first time for Matsumoto Yamaga. In order to measure the strength of the linear relationship between nineteen (19) variables, the correlation analysis is conducted. The Pearson correlation coefficient, r, can take a range of values from +1 to −1. A value of 0 indicates that there is no association between the two variables. A value greater than 0 indicates a positive association; that is, as the value of one variable increases, so does the value of the other variable. A value less than 0 indicates a negative association; that is, as the value of one variable increases, the value of the other variable decreases. Table 2 contains the Pearson correlation coefficient between all pairs of nine variables with the two-tailed significance of these coefficients. All variables correlate fairly well and statistically significant, and none of the correlation coefficients are particularly large; therefore, multicollinearity is not a problem for these data.

Table 1 Descriptive statistics of variables for two games

Variables	N	Min	Max	Total	Ave.	S.D.
Goal	3658	0	1	8	0	0.047
Assist	3658	0	1	5	0	0.037
Shooting	3658	0	1	61	0.02	0.128
Assist of shooting	3658	0	1	43	0.01	0.108
Trapping	3658	0	1	991	0.27	0.444
Dribbling	3658	0	1	46	0.01	0.111
Pass	3658	0	1	1811	0.5	0.5
Centering	3658	0	1	116	0.03	0.175
Through pass	3658	0	1	51	0.01	0.117
Corner kick	3658	0	1	17	0	0.068
Directly free kick	3658	0	1	57	0.02	0.124
Indirectly free kick	3658	0	1	11	0	0.055
Gain ball	3658	0	1	298	0.08	0.274
Get loose ball	3658	0	1	146	0.04	0.196
In penalty area	3658	0	1	76	0.02	0.143
In side of penalty area	3658	0	1	74	0.02	0.141
In 30 m line	3658	0	1	163	0.04	0.206
In vital area	3658	0	1	225	0.06	0.24
In primary area	3658	0	1	35	0.01	0.097

5 The Structural Models

5.1 Results of Hypotheses

Testing the efficacy of the structural model was conducted by AMOS 20, and the major results of analysis for Shonan Bellmare versus Kashima Antlers Model are shown in Table 3, while those for Shonan Bellmare versus Matsumoto Yamaga Model are shown in Fig. 2 and Table 4, respectively. The path diagram highlights the structural relationships. In this diagram, the measured variables are enclosed in boxes, latent variables are circled, and arrows connecting two variables represent relations, and open arrows represent errors.

When SEM is used to verify a theoretical model, a greater goodness of fit is required for SEM analysis [29]; the better the fit, the closer the model matrix and the sample matrix. By means of various goodness-of-fit indexes, including the Goodness-of-Fit statistic (GFI) and adjusted goodness of fit index (AGFI) [34], and the root mean squared error of approximation (RMSEA) [35], the estimated matrix can be evaluated against the observed sample covariance matrix to determine whether the hypothesized model is an acceptable representation of the data.

Table 2 Correlation coefficient

	Goal	Assist	Shooting	Assist of shooting	Trapping	Dribbling	Pass	Centering	Through pass	Corner kick	Directly free kick
Goal	1	−0.002	0.314**	−0.005	−0.029	−0.005	−0.046**	−0.008	−0.006	−0.003	−0.006
Assist		1	−0.005	0.339**	−0.023	−0.004	0.037*	0.078**	0.059**	−0.003	−0.005
Shooting			1	−0.014	−0.079**	−0.015	−129**	−0.024	−0.015	−0.009	0.035*
Assist of shooting				1	−0.066**	−0.012	0.110**	0.255**	0.074**	0.104**	0.007
Trapping					1	−0.069**	−0.604**	−0.110**	−0.072**	−0.042*	−0.077**
Dribbling						1	−0.112**	−0.02	−0.013	−0.008	−0.014
Pass							1	0.092**	0.120**	0.069**	0.114**
Centering								1	−0.022	0.332**	0.040*
Through pass									1	−0.008	−0.015
Corner kick										1	−0.009
Directly free kick											1
Indirectly free kick											
Gain ball											
Get loose ball											
In penalty area											
In side of penalty area											
In 30 m line											

(continued)

Table 2 (continued)

	Goal	Assist	Shooting	Assist of shooting	Trapping	Dribbing	Pass	Centering	Through pass	Corner kick	Directly free kick
In vital area											
In primary area											

	Indirectly free kick	Gain ball	Get loose ball	In penalty area	In side of penalty area	In 30 m line	In vital area	In primary area
Goal	−0.003	−0.014	−0.01	−0.007	−0.007	−0.01	−0.012	−0.005
Assist	−0.002	−0.011	−0.008	0.150**	−0.005	0.028	0.083**	0.300**
Shooting	−0.007	−0.031	0.028	−0.019	−0.019	−0.028	−0.033*	−0.013
Assist of shooting	−0.006	−0.023	−0.022	0.500**	−0.016	0.026	0.342**	0.615**
Trapping	−0.033*	−0.035*	0.052**	−0.072**	−0.022	−0.021	0.056**	−0.054**
Dribbling	−0.006	−0.007	0.052**	0.018	0.019	−0.001	0.053**	−0.011
Pass	0.045**	−0.045**	−0.057**	0.090**	0.079**	0.107**	0.045**	0.094**
Centering	0.019	−0.037*	0.051**	0.335**	−0.026	−0.032	0.129**	0.399**
Through pass	−0.007	−0.018	−0.012	0.130**	0.182**	0.02	0.076**	0.012
Corner kick	−0.004	−0.02	−0.014	0.131**	−0.01	−0.015	0.049**	0.158**
Directly free kick	−0.007	−0.037*	−0.026	0.044**	−0.002	0.037*	0.005	0.056**
Indirectly free kick	1	−0.016	−0.011	−0.008	−0.008	0.061**	0.069**	−0.005
Gain ball		1	−0.025	−0.029	−0.036*	−0.011	−0.039*	−0.029
Get loose ball			1	0.049**	0.02	−0.03	0	−0.006

(continued)

Table 2 (continued)

	Indirectly free kick	Gain ball	Get loose ball	In penalty area	In side of penalty area	In 30 m line	In vital area	In primary area
In penalty area				1	−0.021	0.089**	0.425**	0.557**
In side of penalty area					1	0.120**	−0.037*	−0.014
In 30 m line						1	0.270**	0.02
In vital area							1	0.325**
In primary area								1

*The correlation coefficient is significant (two sides) at the 5 % level
**The correlation coefficient is significant (two sides) at the 1 % level

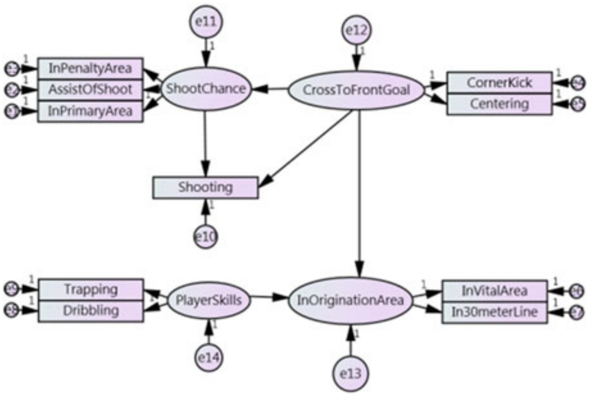

Fig. 2 Shonan Bellmare versus Kashima Antlers Model

Table 3 The path coefficients of Shonan Bellmare versus Kashima Antlers Model

	Shonan Bellmare		Kashima Antlers	
	Std. Weight	*P* value	Std. Weight	*P* value
Shooting chance ← Cross to front goal	0.373		0.986	
In origination area ← Player skills	0.016	0.027		0.997
In origination area ← Cross to front goal	0.009	0.993	0.187	
In primary area ← Shooting chance	0.297		0.324	
Assist of shooting ← Shooting chance	1.525		0.519	
In penalty area ← Shooting chance	2.625		2.769	
Corner kick ← Cross to front goal	0.071	0.905	0.073	0.672
Centering ← Cross to front goal	0.978		0.801	
In vital area ← In origination area	0.647		0.844	
In 30 m line ← In origination area	0.7		0.779	
Dribbling ← Player skills	5.118			
Trapping ← Player skills	−0.012	0.993		0.997
Shooting ← Shooting chance	−0.007	0.829	0.635	0.759
Shooting ← Cross to front goal	−0.007	0.733	−0.665	0.75

In general, fit indexes (i.e., GFI and AGFI) above 0.90 signify good model fit. RMSEA values lower than 0.08 signify acceptable model fit, with values lower than 0.05 indicative of good model fit [35]. The Shonan Bellmare versus Kashima Antlers Model is shown in Fig. 2 and a list of the model's path coefficients in Table 4; CFI = 0.949, AGFI = 0.910, RMSEA = 0.063. Shonan Bellmare versus Matsumoto Yamaga Model is shown in Fig. 3 and a list of the model's path

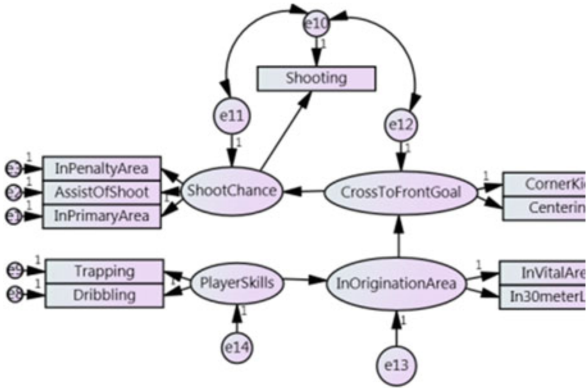

Fig. 3 Shonan Bellmare versus Matsumoto Yamaga Model

Table 4 The path coefficients of Shonan Bellmare versus Matsumoto Yamaga Model

	Shonan Bellmare		Matsumoto Yamaga	
	Std. Weight	*P* value	Std. Weight	*P* value
In origination area ← Player skills	0.05	0.958		0.99
Cross to front goal ← In origination area	−0.121	0.049	−0.202	
Shooting chance ← Cross to front goal	−1.341	0.016	−1.886	
Corner kick ← Cross to front goal	0.495		0.765	
Centering ← Cross to front goal	0.848		0.526	
In vital area ← In origination area	1.167		1.034	
In 30 m line ← In origination area	0.235	0.022	0.461	
In primary area ← Shooting chance	0.839		0.761	
Assist of shooting ← Shooting chance	0.653		0.653	
In penalty area ← Shooting chance	0.682		0.661	
Dribbling ← Player skills	2.79		–	–
Trapping ← Player skills	−0.03	0.958		0.99
Shooting ← Shooting chance	−0.052	0.353	−0.066	0.408

coefficients in Table 5; CFI = 0.950, AGFI = 0.908, RMSEA = 0.062. Since all of our indexes satisfy the cut-off values, our results are regarded as acceptable.

Shonan Bellmare versus Kashima Antlers Model. The results of the research model for Shonan Bellmare versus Kashima Antlers shows the following findings:

- Shonan Bellmare.
  - H1: There is a highly significant, positive relationship between Players' Skills and Origination Area
  - H2: There is a positive but not significant relationship between Origination area and Cross to Front Goal
  - H3: There is a highly significant, positive relationship between Cross to Front Goal and Shooting Chances

Table 5 Reliability tests

FIT indices	Recommended level	Shonan Bellmare versus Kashima Antlers	Shonan Bellmare versus Matsumoto Yamaga
CMIN/DF	5.0 ~2.0 [34]	9.195	7.100
GFI	>0.90 [34]	0.949	0.950
AGFI	>0.90 [34]	0.910	0.908
RMSEA	<0.08 [35]	0.063	0.062
AIC	Smaller values suggest a good fitting	666.093	525.978
p-value	>0.05	0.000	0.000

  - H4: There is a negative and not significant relationship between Cross to Front Goal and Shooting

- Kashima Antlers.
  - H1: There is a highly significant, positive relationship between Players' Skills and Origination Area
  - H2: There is a positive but not significant relationship between Origination area and Cross to Front Goal
  - H3: There is a highly significant, positive relationship between Cross to Front Goal and Shooting Chances
  - H4: There is a negative and not significant relationship between Cross to Front Goal and Shooting
  - H5: There is a positive and not significant relationship between Shooting Chances and Shooting.

The relationship between "Cross to Front Goal" and "In Origination Areas" for Kashima Antlers is positive and highly statistically significant, while that of Shonan Bellmare is also positive and statistically significant but less extent. Kashima's game strategy seems like once lowered the ball from a sideline up to the vital area, and then assembled. As for the relationship of the "shooting" and "scoring chance," a coefficient of Shonan Bellmare is larger, since they finished their play with a shot at the scene to become a chance for them conceivably. As far as Shonan Bellmare versus Kashima Antlers game concerned, while, Kashima played on the counter attack, Shonan Bellmare turned off the play by ending with the last shot; Shonan Bellmare seems like controlling the game from the area of a starting point.

Shonan Bellmare versus Matsumoto Yamaga Model.

- Shonan Bellmare
  - H1: There is a positive but not significant relationship between Players' Skills and Origination Area
  - H2: There is a negative and significant relationship between Origination area and Cross to Front Goal

- H3: There is a highly significant, positive relationship between Cross to Front Goal and Shooting Chances
- H4: There is a positive and highly significant relationship between Cross to Front Goal and Centering
- H5: There is a negative and not significant relationship between Shooting Chances and Shooting

• Matsumoto Yamaga

- H1: There is a positive but not significant relationship between Players' Skills and Origination Area
- H2: There is a negative and highly significant relationship between Origination area and Cross to Front Goal
- H3: There is a negative and highly significant relationship between Cross to Front Goal and Shooting Chances
- H4: There is a positive and highly significant relationship between Cross to Front Goal and Centering
- H5: There is a negative and not significant relationship between Shooting Chances and Shooting.

There is a positive and highly significant relationship between Cross to Front Goal and Centering for Matsumoto Yamaga, while a relationship between Cross to Front Goal and Shooting Chances, and Cross to Front Goal and Centering are high positive and significant for Shonan Bellmare. However, relationships between Shooting Chances and Shooting are negative and not significant for both teams.

The results imply that both teams did not fully take advantage of the shooting chances to gain goals. The Shonan Bellmare versus Matsumoto Yamaga Model suggests that Shonan Bellmare could play a good game when they are able to assemble the game in the starting point area, and use the sidelines efficiently.

6 Summary of Research Results from Shonan Bellmare's Point of View and Future Study

The results suggest that midfielders and forwards of Shonan Bellmare played on the counter attacks, assembling games on the vital area as well as 30 m line to aim goals from sidelines. The tactic of the counter attack is one of the most widely used in football today [36].

The two most vital aspects of the counter attack are the positioning of and passing of the midfielders. The most difficult aspect of this role is the dual requirement of playing with their backs to the opposition's goal as well as being able to quickly read the game ahead of them once they turn with the ball. If one looks at the average positioning of both players, it becomes apparent that they are instructed to sit deep for that purpose alone. And if they lose the ball they are close enough to their defense to be able to recover again. Shonan Bellmare seems to have

Table 6 Result' summary

	Shonan Bellmare versus Kashima Antlers		Shonan Bellmare versus Matsumoto Yamaga	
	(Shonan Bellmare)	(Kashima Antlers)	(Shonan Bellmare)	(Matsumoto Yarrmga)
H1: In origination area ← Player skills	+	+	+	+
H2: In origination area ← Cross to front goal	+	+	−	−
H3: Shooting chance ← Cross to front goal	+	+	−	−
H4: Shooting/centering ← Cross to front goal	−	−	+	+
H5: Shooting ← Shooting chance	−	+	−	−

an established counter attack strategy. However, their formations, consisting of three center back defenders spread out in a flat line across the field, make them difficult to communicate with each other. The analyses of their defense plays would be considered for a future study (Table 6).

Acknowledgments This research has made use of Data Stadium Inc. database.

References

1. Polenghi, C.: J-League history. http://www.goal.com/en-my/news/5286/featured-story/2013/09/09/4248274/j-league-history-part-1-beginnings (2013). Retrieved on 27 Jan 2016
2. Kurzawa, D.: GPS in Sport: Analysis and Determination of Fitness Levels. University of New South Wales. http://www.sage.unsw.edu.au/currentstudents/ug/projects/Kurzawa/introduction.htm (2008). Retrieved on 27 Jan 2016
3. Japan Football Association. Technical Report FIFA World Cup '98', 7–9. 45–56. (1998). (in Japanese)
4. Nakagawa, A.: Acknowledge Technology of Team Play, Coach Manual for Player and Mental Management. Taishukan Publishing, Co., pp. 131—146 (1997)
5. Dawson, B., Appleby, B., Stewart, G.: Analysis of a 16-game winning streak in Australian rules football. In: Reilly, T., Cabri, J., Araújo, D. (eds.) Science and Football, V, vol. 1, pp. 201–204. Routledge, Taylor & Francis Group, Lisbon, Portugal, New York (2005)
6. Reep, C., Benjamin, B.: Skill and chance in association football. J. Roy. Stat. Soc. Ser. A (General) **131**(4), 581–585 (1968)
7. Hughes, M., Franks, I.: Analysis of passing sequences, shots and goals in soccer. J. Sports Sci. **23**(5), 509–514 (2005)
8. Hook, C., Hughes, M.D.: Patterns of play leading to shots in Euro 2000. In: Pass.com. Ed: CPA (Center for Performance Analysis), pp. 295–302. UWIC, Cardiff (2001)
9. Jones, P.D., James, N., Mellalieu, S.D.: Possession as a performance indicator in soccer. Int. J. Perform. Anal Sport **4**(1), 98–104 (2004)

10. Mackenzie, R., Cushion, C.: Performance analysis in football: a critical review and implications for future research. J. Sports Sci. **31**(6), 639–676 (2013)
11. Bloomfield, J., Polman, R., O'Donoghue, P.G.: The 'Bloomfield movement classification': motion analysis of individual players in dynamic movement sports. Int. J. Perform. Anal. Sport **4**(2), 20–31 (2004)
12. Coelho e Silva, M., Figueiredo, A., Sobral, F., Malina, R.M.: Profile of youth soccer players: Age–related variation and stability. In: Coelho e Silva, M., Malina, R.M. (eds.) Children and Youth in Organized Sports. Coimbra University Press, Coimbra, pp. 189–198 (2004)
13. Kan, A., Shiokawa, M., Okihara, K., Soon Choi, C., Usui, S., Yanagihara, T.D.E.: The movement of players and the team: comparing two games, Japan versus UAE and J-Leaguegame [Abstract] Part II: Game activity and analysis. J. Sports Sci. **22**(6), 500–520 (2004)
14. Armatas, V., Yiannakos, A., Sileloglou, P.: Relationship between time and goal scoring in soccer games: analysis of three world cups. Int. J. Perform. Anal. Sport. **7**(2), 48–58 (2007)
15. Ensum, J., Pollard, R., Taylor, S.: Applications of logistic regression to shots at goal in association football: calculation of shot probabilities, quantification of factors and player/team. J. Sports Sci. 504 (2004)
16. Pollard, R., Reep, C.: Measuring the effectiveness of playing strategies at soccer. Statistician **46**, 541–550 (1997)
17. Wisbey, B., Montgomery, P.G., Pyne, D.B., Rattray, B.: Quantifying movement demands of AFL football using GPS tracking. J. Sci. Med. Sport **13**(5), 531–536 (2010)
18. Nakayama, M., Haranaka, M., Sasaki, R., Tabei, R., Kuwabara, T., Hirashima, Y.: Comparative analysis of attack-related game aspects in the Japanese University Football League, Japanese J-League, and UEFA Champions League, Comparative Analysis of Attack–related Game Aspects in the Japanese University Football League, Japanese J-League. Football Sci. **12**, 58–66 (2015)
19. James, N., Jones, P.D., Mellalieu, S.D.: Possession as a performance indicator in soccer. Int. J. Perform. Anal. Sport **4**, 98–102 (2004)
20. Bate, R.: Football chance. Tactics and strategy. In: Reilly, T., Less, A., Davies, K., Murphy, W. (eds.) Science and Football V, pp. 293–301. E and FN Spon, London (1988)
21. Carmichael, F., Thomas, D., Ward, R.: Production and efficiency in association football. J. Sports Econ. **2**(3), 228–243 (2001)
22. Dawson, P., Dobson, S., Gerrard, B.: Estimating coaching efficiency in professional team sports: evidence from english association football. Scott. J. Polit. Econ. **47**, 399–421 (2000)
23. Garganta, J.: Análisis del juego del fútbol. El recorrido evolutivo de las concepciones, métodos e instrumentos. Revista de Entrenamiento Deportivo, Tomo, XIV, 2, 6–13. (2000)
24. Hadley, L., Poitras, M., Ruggiero, J., Knowles, S.: Performance evaluation of national football league teams. Manag. Decis. Econ. **21**, 45–56 (2000)
25. Hughes, M.D.: Notational analysis. In: Reilly, T., Williams, M. (eds.) Science and soccer, pp. 245–264. Routledge, London (2003)
26. Hughes, M.D., Bartlett, R.: The use of performance indicators in performance analysis. J. Sports Sci. **20**, 739–754 (2002)
27. McGarry, T., Franks, I.: The science of match analysis. In: Science and Soccer V, PP. 265–275. Routledge, London (2003)
28. Gómez López, M., Álvaro, J.: El tiempo de posesión como variable no determinante del resultado en los partidos de fútbol. El Entrenador Espanol, **97**, 39–47 (2002)
29. Byrne, B.M.: Structural Equation Modeling Using AMOS. Basic Concepts, Applications, and Programming, 2nd edn. Routledge, New York (2010)
30. Cudeck, R., du Toit, S., Sörbom, D. (eds.): Structural Equation Modeling: Present and Future. Scientific Software International, Chicago (1992)
31. Jöreskog, K.G.: New developments in LISREL—analysis of ordinal variables using polychoric correlations and weighted least squares. Qual. Quant. **24**, 387–404 (1990)
32. Mueller, R.: Structural equation modeling: back to basics. Struct. Equ. Model. **4**, 353–369 (1997)

33. Yuan, K.H., Bentler, P.M.: Mean and covariance structure analysis: theoretical and practical improvements. J. Am. Stat. Assoc. **92**, 767–777 (1997)
34. Tabachnick, B.G., Fidell, L.S.: Using Multivariate Statistics, 5th edn. Allyn and Bacon, New York (2007)
35. Browne, M.W., Cudeck, R.: Alternative ways of assessing model fit. Sociol. Methods Res. **21**, 230–239 (1993)
36. Nyari, C.: The art of counter attack—a look at Somka's efficient Hannover Side. Sundesliga Fanatic, 18 Apr 2011, http://bundesligafanatic.com/the-art-of-the-counter-attack-%E2%80%93-a-look-at-slomka%E2%80%99s-efficient-hannover-side/ (2016). Retrieved on 10 Feb 2016

Team Building Program for Enhancement of Collective Efficacy: The Case of a University Baseball Team in Japan

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Abstract The purpose of this study was to examine the effects of the experience of TB among a university baseball team's members from the viewpoint of collective efficacy. For this purpose, we carried out a TB program with one university baseball team (102 males, 6 female) in 2011. This TB program had a theoretical background of transactional analysis. The average age of the 108 participants was 19.99 years (±1.417). We used the Collective Efficacy Questionnaire for Sports (Short et al. in Meas Phys Educ Exerc Sci 93:181–202, 2005 [1]), to examine the effects of TB. Responses to this questionnaire collected from the participants before and immediately after the TB intervention. A paired t-test showed that each factor of collective efficacy was higher than before the TB experience ($p < 0.05$). The practical implication of these findings suggested that implementation of TB is effective from the viewpoint of collective efficacy.

Keywords Organizational development · Measurements of effects · Team building · Collective efficacy · Team sports · Intervention

1 Introduction

Teams used in various situations. For example, job execution and business solutions usually performed by teams in recent years. Therefore, a synergy effect expected to result by combining limited resources within a team. What is the key

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factor of an excellent team? This proposition is an eternal issue for sport teams, too. Understanding the key factors that make an excellent team is an ongoing issue for sports teams. Collective efficacy has been drawing attention in recent years. Collective efficacy refers to a "group's shared belief in its conjoint capabilities to organize and execute the courses of action required to produce given levels of attainments" [2]. Actually, much research has shown that there is a positive relationship with collective efficacy and team effectiveness [3–5]. In this study, we focused on team building (TB) as a factor for improving collective efficacy. TB is one of the methods of organization development (OD) that has frequently used in the industrial field. Recently, TB has also applied to the education and sports fields. However, little is known about the effects of TB in the field of sports. The purpose of this study was to examine the effects of the experience of TB among a university baseball team from the viewpoint of collective efficacy. For this purpose, we carried out a TB program designed by Kitamori with one university baseball team (102 males, 6 female) in 2011.

2 Methods

2.1 Participants

This research carried out in one university baseball team consisted of 108 members. Through the informed consent procedure, a total 108 members (male = 102, female = 6) agreed with this study (response rate = 100 %, cover rate = 100 %). The mean age was 19.99 (SD = ±1.42) years old.

2.2 Team Building (TB) Program

The Team building program based on OD methods, had the theoretical background of the Transactional Analysis—focused on human relations. Then, this program had been designed by Kitamori who was structured the OD program in Japan. In this program, learning experience and many of the image replacement performed (Table 1).

2.3 Measures (Procedure)

We used the Collective Efficacy Questionnaire for Sports [1], to examine the effects of TB. Responses to this questionnaire collected from the participants before and immediately after the intervention of TB program.

Table 1 The TB program of this study

First day		
Time	Contents	Purpose
10:00	1. introductions	Description of the program
	2. Tool I	The discovery of learning styles
	3. Tool II	Self-introduction
12:00	Lunch time break	
	4. Tool III	The discovery and understanding of life position
	5. Individual work	Summary of the things that I noticed from the advice sheet
16:30	6. Summary	Day 1 summary
Second day		
10:00	7. Tool IV	Group discussions based on the consensus
	8. Group discussions	Mutual consideration of the action plan
12:00	Lunch time break	
	8. Group discussions (Continuation)	Mutual consideration of the action plan (Continuation)
16:30	9. Summary	Summarize the two days

2.4 *Analysis Procedure*

To compare with each scores of pre and post, we carried out paired t-test using statistical analysis software (SPSS18.0) of IBM Corp.

3 Results

The paired t-test showed that the score of subscales were higher than before the experience of TB program ($p < 0.001$) (Table 2). Then, Collective Efficacy were enhancement after the TB program.

Table 2 The result of paired *t*-test

Factors	Pre		Post		Pre-post	*t*-value	95 % CI		*p*
	M	SD	M	SD			Up.	Low.	
1. Ability	3.22	0.80	3.50	0.71	−0.28	−2.65	−0.485	−0.071	*
2. Unity	3.57	0.63	3.94	0.58	−0.37	−4.46	−0.537	−0.208	**
3. Persistence	3.11	0.62	3.49	0.63	−0.38	−4.41	−0.554	−0.212	**
4. Preparation	3.41	0.64	3.82	0.94	−0.40	−3.64	−0.622	−0.185	**
5. Effort	3.34	0.59	3.74	0.60	−0.39	−4.79	−0.556	−0.232	**

*$p < 0.05$ **$p < 0.001$

4 Discussions

This study, carried out TB program for two days to university baseball team, was to compare the scores of each factor in the intervention before and immediately after the TB. As a result, it observed that tends to increase the score of all factors after the intervention. These results suggested that the collective efficacy of university baseball team's members were enhancement by implementation of TB program. Self-efficacy that conceptualized by Bandura is believed to be affected from a variety of sources. Bandura (1997) theorizes that they are a product of a complex process of self-appraisal and self-persuasion that relies on cognitive processing of diverse sources of efficacy information. He categorized these sources of information as (1) past performance accomplishment, (2) vicarious experience, (3) verbal persuasion, and (4) physiological states [5]. Then, the source of collective efficacy also believed to the same as self-efficacy. However, the results of this study showed that collective efficacy was enhancement without these four sources. In other words, we can considered to discovery of new resources. We would like to try to guess about why the difference in the score before and after the intervention of TB. The characteristic of the TB program, which was adopted in this study is to obtain the "new awareness" for the environment (self, others, and organization) in a short time. Therefore, image exchange is widely used in the TB program to promote mutual understanding and interactions of the participants. In addition, it intended to learn effective communication and teamwork based on experience. The cause of improvement of each score, probably they learned an important point of the building to cooperate systems with fellow through the TB program. In addition, one of the remarkable result that collective efficacy of university baseball team's members were enhancement as short time at least for two days. From the previous studies, collective efficacy is a useful factor to predicting the effectiveness and outcomes. Therefore, the results of this study, It can be said to be an important discovery from the viewpoints of both practical and academic.

5 Conclusions

As the combined results, this study provided the following conclusions; (1) Collective efficacy of university baseball team members were enhancement after the intervention of TB program. (2) Collective efficacy of university baseball team's members can be enhancement at least for two days through the TB program.

6 Future Work

The result of this study just compared with before and after the intervention of TB program. That had not compared to the control groups. In the future, it is necessary to longitudinal research and compared with the control groups to examine the effects. In there, it can expected to have obtained a high level of evidence findings.

References

1. Short, S.E., Sullivan, P., Feltz, D.L.: Development and preliminary validation of the collective efficacy questionnaire for sports. Meas. Phys. Educ. Exerc. Sci. **9**(3), 181–202 (2005)
2. Bandura, A.: Social foundations of thought and action: a social cognitive theory, p. 477. Prentice-Hall, Inc. (1986)
3. Myers, N.D., Feltz, D.L., Short, S.E.: Collective efficacy and team performance: a longitudinal study of collegiate football teams. Group Dyn. Theory Res. Pract. **8**(2), 126–138 (2004)
4. Myers, N.D., Payment, C.A., Feltz, D.L.: Reciprocal relationships between collective efficacy and team performance in women's ice hockey. Group Dyn. Theory Res. Pract. **8**(3), 182–195 (2004)
5. Wu, J.B., Tsui, A.S., Kinicki, A.J.: Consequences of differentiated leadership in groups. Acad. Manag. J. **53**(1), 90–106 (2010)

Analysis of an Olympic Scale of a Recurve Bow Riser on the Basis of Malaysian Under 15 and Under 17 Archers

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Abstract Recurve bow is the only type of bow that used in Olympic Games. To date, none of this bow that suits to Malaysian junior archers. This paper aims to analyze a recurve bow riser on the basis of Malaysian anthropometry. Anthropometric data of Malaysian population was gathered to analyze the loads during drawn bow. A static structural analysis of the Matrix riser was executed on a final design of recurve bow riser. The finding from this study shows that the maximum displacement of recurve riser is correspondence to the established previous study. It can be concluded that the design of recurve bow riser can sustain the force applied by Malaysian junior athletes when they aim the target board at a full drawn bow position. The developed bow riser can be very beneficial for both athletes and coaches during training.

Keywords Recurve bow · Malaysian anthropometry · Static structural analysis

1 Introduction

Recurve archery is the only type of bow in archery sport that used in Olympic Games. Historically, archery has been used in ancient days and firstly appeared in Olympic Games in 1900 [1]. The usage of recurve bows has been changed periodically from simple wooden bow to high-technology recurve bows as time changed. Nowadays, there are many kinds of recurve bows use in Olympic Games as the athletes will choose the most comfortable one. Figure 1 showed the component of recurve bow and its terminology used in recurve bows. During Olympic competitions, only bow that consists of grip, riser, two flexible limbs, bowstring,

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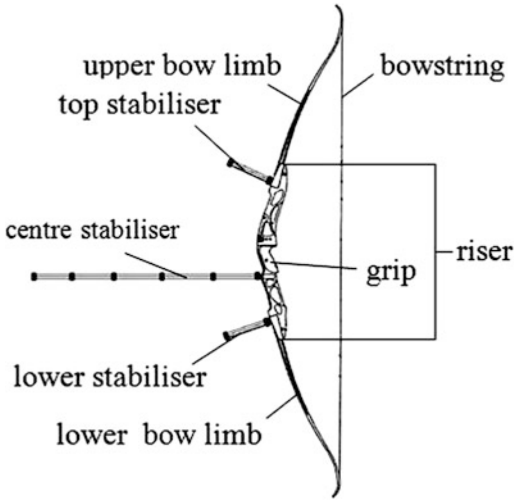

Fig. 1 Recurve bow and its terminology [1]

stabilisers and torque flight are permitted (see Fig. 1). Technically, a good riser must possess features of lightweight and high stiffness [2]. However, there is enormous challenge for the manufacturers to meet these demands. Addition to that, a bow that meet the strength and size of archers lead to their success [3].

Today, the interest on recurve bow have dramatically increased as a results from many innovations of recurve bow on their materials and techniques. Researchers have presented their work on recurve bow related to the arrow, physiological and mechanical dynamic of recurve bow [1–3]. The parametric optimization of war bow has been studied by Demir and Ekici [4] and concluded that thickness is the most significant variables that affect the draw weight of the war bow. Apart from that, the archers who refrained from gripping the bow handle yield a better muscle activation pattern [5]. Although with the correct techniques available, Malaysian junior archers are still facing a few problems as they are totally depending on imported bow equipment. Also, using a bow that are not anthropometrically fit may reduce the performance of young Malaysian archers and lead to various ergonomic problems such as musculoskeletal disorder (MSD). Many researchers have agreed that body dimensions play a critical role in performance and safety of a product [6–9]. Therefore, a recurve bow that suit to Malaysian junior archers may enhance the performance of the archers.

The objective of this paper is to analyze displacement of recurve bow riser on the basis of Malaysian anthropometry. The significance of this study leads to produce a new riser that suit to Malaysian junior athletes especially, under 15 (U–15) and under 17 (U–17) archers. It is also aiming at enhancing archers' performance and reduce any related injuries. A thorough calculation of forces acting on the drawn riser are presented in this paper. Employment of anthropometric data, analysis of loads and structural analysis was discussed in the next section. Finally, conclusion was draws in the last section of this paper.

2 Methods

2.1 Anthropometric Data

Anthropometric data was employed from Malaysian anthropometric database obtained by Dawal et al. [9]. The data from 41 high schools students aged from 13 to 17 years old took part in the study. The arm span data was taken from 21 static data measurement that was provided in the Malaysian anthropometric database (see Table 1). Draw length can be measured by adding 1 ¾ inch to the value of true draw length or draw length from pivot point (DLPP) at full drawn condition [10]. However, this method could lead to inaccurate reading as the value obtain could vary due to poor alignment, shoulder position, anchor point, head position and poor posture of an archer. To minimize the error, the value of arm span is divided by 2.5 [11, 12]. Figure 2 illustrated the image of how measurement of arm span was taken. In a standing position, both arms were reached out and measurement was taken from tip of middle finger to another tip of middle finger.

2.2 Load Analysis on Recurve Riser

Loads applied to a 25 inch Matrix (HOYT) recurve riser was analyze during full drawing condition. During drawing, it can be assumed that there is a static equilibrium force acting on the recurve riser. Figure 3 showed a sketch of an athlete in a drawn position with all the external forces involve on the recurve riser during that phase. Figure 4 illustrated the free body diagram of a drawn bow at limb pocket that was derived from Fig. 3.

Table 1 Arm span data of Malaysian U-15 and U-17 [9]

Anthropometry	Male (cm)	Female (cm)
Arm span	175.05	163.46

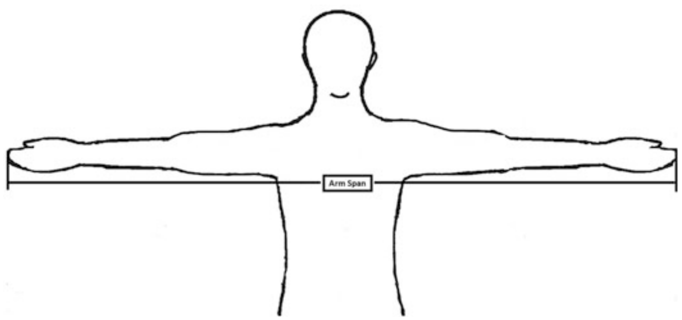

Fig. 2 Arm span measurement method

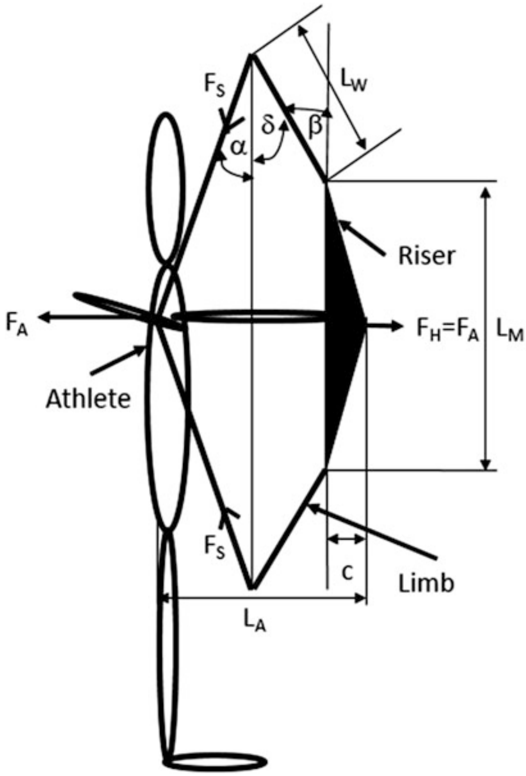

Fig. 3 Sketch of an athlete drawing a bow with the external forces involved. Where F_A = draw weight, F_H = force that holds the drawn bow, F_S = string force, L_A = draw length, L_M = length of the riser L_W = length of limb, c = width of riser

The static equilibrium forces of a drawn bow equation obtained was shown in Eqs. (1)–(3) (see Fig. 4). The Eqs. (4) and (5) showed the equation for x and y component in the string force, F_S obtain from Fig. 4.

$$\uparrow + F_Y \qquad F_{BP} = F_{SY} \tag{1}$$

$$\rightarrow + F_X \qquad F_{BS} = F_{AS} + F_{SX} \tag{2}$$

$$\circlearrowleft + M \qquad a \cdot F_{AS} = b \cdot F_{SX} + e \cdot F_{SY} \tag{3}$$

For x-component and y-component in the F_S:

$$F_{SX} = F_S \cdot \sin(\alpha + \delta + \beta) \tag{4}$$

$$F_{SY} = F_S \cdot \cos(\alpha + \delta + \beta) \tag{5}$$

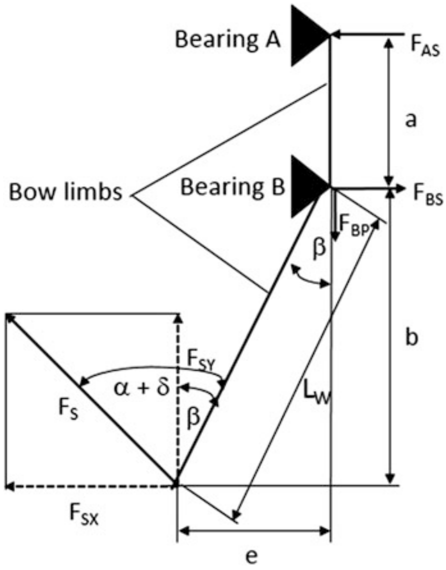

Fig. 4 Free body diagram of the external forces at the limb pocket involved during drawn bow. Where F_{BP}, F_{AS}, F_{BS} = forces acting at the limb pocket that corresponds to Fig. 3, a = distance between bearing A and B, b = Length from bearing B to the tip of bow limb, e = Horizontal length from the tip of the bow limb to the straight vertical line of bearing B

As the aim of the equation is to determine the value of F_{BP}, F_{AS} and F_{BS}, the substitution of Eqs. (4) and (5) into Eqs. (1)–(3) yield the new equation and presented as Eqs. (6)–(8). These equations are correspond to the equation suggested by Edelmann-Nusser et al. [13].

$$F_{BP} = F_{SY} = [F_A/(2 \cdot \sin\alpha)] \cdot \cos(\alpha + \delta - \beta) \tag{6}$$

$$F_{AS} = (F_A \cdot L_W)/(2a \cdot \sin\alpha)\,[(\sin(\alpha + \delta - \beta) \cdot \cos\beta + \cos(\alpha + \delta - \beta) \cdot \sin\beta)] \tag{7}$$

$$F_{BS} = F_A/(2 \cdot \sin\alpha)\,[(\sin(\alpha + \delta - \beta) + (L_W/a)(\sin(\alpha + \delta - \beta) \cdot \cos\beta + \cos(\alpha + \delta - \beta) \cdot \sin\beta)] \tag{8}$$

The value of F_{BP}, F_{AS} and F_{BS} were obtained by using Eqs. (6)–(8). In determining all the unknown values from the equations, a bow with 25 inch recurve riser was selected as it is used by Malaysian junior athletes. The draw length, L_A of the recurve bow was set to 654–702 mm (26″–28″). As the 95th percentile arm span data from Malaysian U-15 and U-17 are maximum at 702 mm, minimum 710 mm draw length were used. The draw length calculated could be vary starting from 710, 760 and 810 mm (28″, 30″ and 32″,), respectively. The draw weight, F_A for both $L_{A.}$ were 169 N (38 lbf) and 178 N (40 lbf), respectively as shown in force-draw

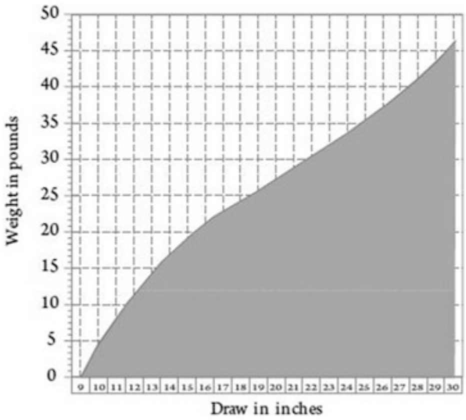

Fig. 5 Force-draw curve [14]

curve in Fig. 5. Therefore, as for safety margin for the riser, 200 N was used for the F_A in static structural analysis. The trigonometric and geometric variables were calculated by using the given information.

2.3 *Static Structural Analysis of the Loads*

A three-dimensional (3-D) solid Computer-Aided Design (CAD) model of 25-inch Matrix (HOYT) recurve riser was modeled by using Solidwork software. It was created based on 3-D scanning image obtained from FARO arm 3-D scanner.

The finite element analysis (FEA) was performed by using Autodesk Simulation Mechanical 2015 software. The material used in this analysis is the aluminum alloy as it is the material used in the manufacturing of recurve riser. The value of Young Modulus, Poisson ratio, density of the aluminum alloy, tensile yields strength and tensile ultimate strength are shown in Table 2.

The mesh size is set to 70 %. Moreover, convergence test was conducted to make sure that the mesh size used was at the optimum. The number of meshes used is 36,500 elements.

Table 2 The material properties of aluminum alloy [15]

Material properties	Value
Young modulus	7.1^10 Pa
Poisson ratio	0.33
Density	2770 kg/m^3
Tensile yields strength	2.8^8 Pa
Tensile ultimate strength	3.1^8 Pa

3 Results and Discussion

3.1 Load Analysis

The values of F_{BP}, F_{AS} and F_{BS} were obtained after substitution of trigonometric and geometric values into Eqs. (6)–(8) at a draw weight of 200 N. Table 3 shows the values of F_{BP}, F_{AS} and F_{BS} computed from the calculation.

Table 3 shows the value of trigonometric, geometric and forces of F_{BP}, F_{AS} and F_{BS} obtained at a draw weight, F_A is 200 N. Value of L_M same for all size of L_A which is 635 mm (25″) riser as this size of riser currently used by Malaysian junior athletes. Meanwhile, L_W was obtained as 1727 mm (68″) bow length was used. Reilly [11] has suggested using 1727 mm (68″) bow length with the L_A that lies between 654–702 mm (26″–28″). The ***a*** is the value of limb and limb pocket that are standardized from different manufacturers. The ***c*** was measured from the 25″ recurve riser.

The F_{BP}, F_{AS} and F_{BS} for small draw length, the L_A outperformed the medium and large L_A. One possible explanation is that smaller bow length yields the maximum energy transfer from bow to arrow. Another reason is that, limb acts as energy storing portion for the above and below riser [16].

3.2 Analysis on Recurve Riser

The Fig. 6 showed the results of the forces acting at the limb pocket of the recurve riser during full drawn condition. The static structural analysis that was conducted on the recurve riser is shown in Fig. 7. The maximum displacement of recurve riser

Table 3 The forces F_{BP}, F_{AS} and F_{BS} obtained from three different size of draw length, L_A

Variables	Size of draw length, L_A		
	710 mm (Small)	760 mm (Medium)	810 mm (Large)
L_M		635	
L_W		546	
α	22.5°	25°	27°
β	22.5°	24°	26°
δ	34°	36°	39°
a		75	
c		86	
F_A		200	
F_{BP}	217	190	170
F_{AS}	1580	1500	1459
F_{BS}	1725	1642	1600

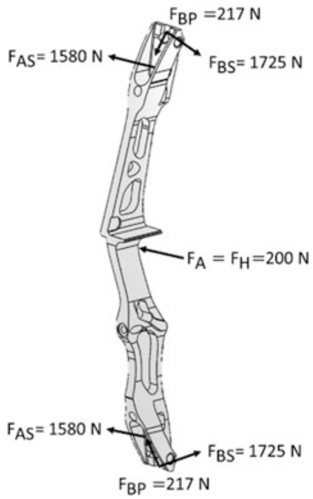

Fig. 6 Force-draw curve

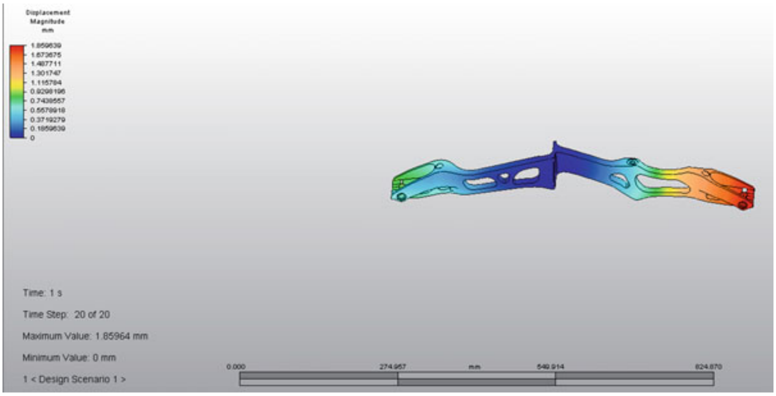

Fig. 7 Force-draw curve

is 1.85 mm. Edelmann-Nusser et al. [13] have conducted a study to design a recurve riser that have a comparable stiffness to RADIAN model. This results of the displacement analysis showed a strong agreement with an established study produced by Edelmann-Nusser et al. [13]. It is because a correct draw length and bow length lead to a higher accuracy of arrow propel to the target board [16]. The value of maximal displacement was obtained after all the values in Table 3 was used in the finite element analysis.

4 Conclusion

The results showed that the maximum displacement of this riser has reached a good correspondence with the established studies. Malaysian junior archers could use 25″ Matrix (Hoyt) recurve riser with 710 mm draw length and 68″ bow length. However, the results obtained in this study is very limited as it focus on the displacement of the recurve riser. The current study merely focused on the riser that made of the aluminum alloy. The analysis and investigation of the riser that made of different materials specifically a hybrid of natural and synthetic fibers must be executed and compared with the aluminum alloy.

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References

1. Heller, M.: Evaluation of arrow release in highly skilled archers using an acoustic measurement system. Procedia. Eng. **34**, 532–537 (2012)
2. Tinazci, C.: Shooting dynamics in archery: a multidimensional analysis from drawing to releasing in male archers. Procedia. Eng. **13**, 290–296 (2011)
3. Ganter, N., Matyschiok, K.C., Partie, M., Tesch, B., Edelmann-Nusser, J.: Comparing three methods for measuring the movement of the bow in the aiming phase of Olympic archery. Procedia. Eng. **2**(2), 3089–3094 (2010)
4. Demir, S., Ekici, B.: Optimization of design parameters for Turkish Tirkeş (war) bow. Compos. B Eng. **66**, 147–155 (2014)
5. Ertan, H.: Muscular activation patterns of the bow arm in recurve archery. J. Sci. Med. Sport **12**(3), 357–360 (2009)
6. Parkinson, M.B., Reed, M.P.: Creating virtual user populations by analysis of anthropometric data. Int. J. Ind. Ergon. **40**(1), 106–111 (2010)
7. Shahida, M.N., Zawiah, M.S., Case, K.: The relationship between anthropometry and hand grip strength among elderly Malaysians. Int. J. Ind. Ergon. **50**, 17–25 (2015)
8. Fryar, C.D., Gu, Q., and Ogden, C.L.: Anthropometric reference data for children and adults: United States, 2007–2010. Vital and Health Statistics. Series 11, Data from the National Health Survey, (252), 1–48 (2012)
9. Dawal, S.Z.M., Zadry, H.R., Syed Azmi, S.N., Rohim, S.R., Sartika, S.J.: Anthropometric database for the learning environment of high school and university students. Int. J. Occup. Safety Ergon. **18**(4), 461–472 (2012)
10. ATA: 'Guideline for ATA Non-Compound Bow Draw Weight Specification', In: (Ed.)^(Eds.): 'Book Guideline for ATA Non-Compound Bow Draw Weight Specification'. Archery Trade Association (2008)
11. Reilly, P.J.: 'What Size Recurve Bow Is Right For Me?', in Editor (Ed.)^(Eds.): 'Book what size Recurve Bow Is Right For Me?'. Lancaster Archery Supply, Inc. (2015)
12. Pellerite, B.: 'Idiot Proof Archery-How To Shoot Like A Pro—Step By Step'. Robinhood Video Productions Inc. (2001)

13. Edelmann-Nusser, J., Heller, M., Clement, S., Vajna, S., Jordan, A.: Lightweight design optimization of a Bow Riser in Olympic Archery applying evolutionary computing. Eur. J. Sport Sci. **4**(3), 33–51 (2004)
14. FITA: 'FITA Coach's Manual Intermediate Level', in Editor (Ed.)^(Eds.): 'Book FITA Coach's Manual Intermediate Level'. World Archery Federation (2007)
15. Kaufman, J.G.: 'Properties of Aluminum Alloys: Tensile, Creep, and Fatigue Data at High and Low Temperatures'. ASM international (1999)
16. Elliot, M.: 'Reference Guide for Recurve Archers', in Editor (Ed.)^(Eds.): 'Book Reference Guide for Recurve Archers' (4th edn.) (2002)

Simply Complex: Are LED Outdoor Activities Complex Sociotechnical Systems?

Tony Carden and Paul M. Salmon

Abstract Although typically applied in safety-critical domains such as aviation, transport, and nuclear power, there is a growing body of research focusing on the application of sociotechnical systems theory to led outdoor activity systems. Antagonists of this approach have argued that led outdoor activities are simple and therefore that a complex sociotechnical systems approach is invalid and unwarranted. This paper seeks to determine whether led outdoor activity systems are complex by comparing their characteristics to established characteristics of complexity theory and sociotechnical systems theory. Features of led outdoor activity work systems are decomposed and compared with theoretical benchmarks of complexity. The findings show that systems of work that afford these simple experiences are indeed both complex and sociotechnical in nature. It is concluded that application of sociotechnical systems theory and methods is both appropriate and required to attain improvements in practice and safety. Implications for further research and practice are discussed.

Keywords Adventure activities · Adventure education · Complexity · Outdoor activities · Outdoor education · Outdoor recreation · Sociotechnical systems

1 Introduction

Worldwide, led outdoor activities represent an important form of active recreation, and include hiking (also known as bushwalking, trekking or tramping), paddle sports (including rafting, canoeing and kayaking), roped activities (including abseiling, rock climbing and challenge ropes courses) and snow sports (such as

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skiing, snowboarding and snow shoeing). Programs of one or more of these activities are commonly run by schools, community clubs or organisations such as Scouts, or private organisations that offer their services to the public. The aims of such programs can be educational, recreational or therapeutic. In educational and therapeutic applications, the activities are often used as metaphors and the participant's experience of them as a catalyst for learning or personal development.

The led outdoor activity sector experiences adverse events that can cause injury, and in the worst cases, multiple fatalities. Examples of recent major incidents in this sector include the Mangatepopo gorge incident in which six year 12 students and their teacher drowned during a gorge walking activity in in the Tongariro National Park, New Zealand [1] and 12 year old Kyle Vassil's drowning in a waterhole whilst on school camp in Toolangi, Victoria [2]. In response to this, there is a growing body of research in which a systems thinking approach has been adopted in an attempt to understand and prevent injury during led outdoor activities. For example, systems analyses of fatal incidents have identified multiple contributory factors related to various different actors, equipment, processes, and organisations [1, 3]. Further, research examining more common injury incidents has revealed similar findings, showing that these also involve multiple contributory factors [4]. Accordingly, the need for a systems thinking-based approach to injury prevention in this sector has been emphasised [5].

The systems thinking approach has traditionally been applied in high risk safety critical systems such as aviation, process control, and surface transportation. Part of the justification for such applications is that these systems are highly complex and dynamic. Likewise, the recent applications of systems thinking in the led outdoor context is based on the notion that led outdoor recreation systems are complex, dynamic systems and exhibit many of the characteristics that are discussed in relation to complexity and sociotechnical systems.

For some who work in the led outdoor activity domain, however, this premise seems counter-intuitive, given the apparent simplicity of the product of their work. For example, antagonists have argued that there is nothing more involved than people and the natural environment and therefore that using systems thinking theories and methods is neither valid nor warranted. Trekking in a remote wilderness or paddling with a small group along an unspoiled coastline conjure images of a simple life, far removed from the busy-ness of modern, urban living. Indeed, these examples and many other experiences available for people to spend time in nature do afford a simplification of daily life. Daily routines, ubiquitous technology, noise and pollution can be left behind for a while.

This paper examines the characteristics of led outdoor activity systems and compares them to the core characteristics of complexity theory, sociotechnical systems theory, and contemporary models of accident causation. The aim is to determine whether led outdoor activity systems are indeed complex in nature, and thus whether the growing body of research that adopts a systems approach is warranted.

2 What Is a Complex Sociotechnical System?

Before outlining the case study analysis it is first worth clarifying what it is that makes a system complex and sociotechnical in nature. Sociotechnical systems are defined widely in Human Factors and Cognitive Ergonomics literature as systems of work that comprise social subsystems (people) interacting with technical subsystems (devices, interfaces and work practices) in pursuit of a common goal.

The distinction between complex and simple systems is not necessarily obvious or straightforward and various authors have discussed a range of key characteristics that are indicative of complexity (e.g. [6, 7]). Characteristics commonly attributed to complex systems include openness (matter or energy is exchanged with the external environment), equifinality (system goals can be achieved via multiple pathways), adaptiveness (the system has a capacity to adapt to changes in its internal and external environment), interdependence (system elements are dependent on multiple other system elements), path dependence (the past is co-responsible for behaviour in the present), systems complexity (the system is complex rather than its components), continuous inputs from components (inputs need to be made at all times to maintain system functioning), and non-linear interactions (small actions can interact to create large events) [7].

While a number of scholars, including Vicente [8] and Carayon [9] have offered defining characteristics of complexity in sociotechnical systems, some of these lists are of most relevance to systems of work that include prominent use of computer technology [8, 9]. Accordingly, Cilliers' characteristics [6] have been used here as they include the general principles identified by others but are more generic about technology and are therefore more suited to analysis of the led outdoor activity domain.

3 Methods and Sources

A case study approach was adopted whereby the work systems that support typical led outdoor activity programs were considered. Specifically, a relatively simple example of a led outdoor activity system was analysed to determine the extent to which it meets established criteria that define complex sociotechnical systems. The characteristics of this system were then compared with those of two other typical styles of led outdoor program. On the basis of this comparison, an assessment was then made of the extent to which the latter two programs meet the criteria for complex sociotechnical systems.

Whilst some sociotechnical systems methods analyse system structure and operation separately (e.g. [8]), this study analysed systems in action. This allowed the identification and integration of entities that arise as temporary constellations of other entities, forming to meet emergent activity demands and then dissolving once the demand is met. The identification of these transient entities as system elements, each with its own properties, constraints and affordances, may improve the capacity of the model to predict system behaviour.

The three work systems considered include:

1. A work system that supports a three day trek for a small group in a semi remote area,
2. A work system that supports a five day multi activity school outdoor education program; and
3. A work system that supports a ten day walking and paddling expedition in a remote area.

Actors, objects and processes involved in each of these systems were identified from interviews with a subject matter expert (SME) who has over ten years' experience managing similar programs for an Australian organisation. The system entities identified for the three day trek were then allocated to levels of the Uploads Framework, a representation of the led outdoor activity domain based on Rasmussen's risk management framework [10]. This enables the composition of the system to be determined along with the relationships evident between different components.

Relationships between entities and their placement in the domain hierarchy were identified through discussion between the analyst and the SME. A sociotechnical system map was developed showing the main entities in the system and some examples of temporary, emergent entities. A persistent entity exists in this system for the duration of the system's life; that is, the persistent entities exist throughout the entire activity from commencement to completion of the program. Temporary or transient entities emerge in response to both planned and unplanned situations. For example, a cooking team is a transient entity with its own unique properties which may form to prepare an evening meal. A temporary rain shelter is an entity that may be spontaneously built in response to an unexpected downpour. The resulting sociotechnical system map was then verified by a second SME with a similar level of experience to the first.

Any system can in principle be decomposed down to ever finer levels of resolution. For example, each raindrop, each tree branch, each hair on the head of a participant could be considered as an individual element in this system. The focus of the present analysis was system effects on participants, both beneficial, intended outcomes and undesirable accidents. Therefore the resolution level is that of individual participants and the other people and objects that interact with them within the system boundary.

The nature of this system and the scope of this study do not allow all possible system entities at the focus level of resolution to be shown. In particular, only four examples of temporary entities are shown, although the potential exists for many more of these to arise. However, the representative examples included in the system map should be sufficient to gauge whether or not this system meets the criteria for complexity.

Definitions of the characteristics of complex systems were drawn from Cilliers' "Complexity and Postmodernism: Understanding Complex Systems" (Cilliers [6]). Characteristics of the mapped system were then compared with each of these criteria.

4 Case Study

The three day trek is a walking journey for a single group of 12 new members of a community bushwalking club and one experienced leader in a semi-remote area in south eastern Australia in October. The goal of the activity is to help participants develop the practical skills of self-contained outdoor living, help group members get to know each other and to create opportunities for a deeper connection with nature. The walk is planned to take three days and the group will camp each night, using tents and other equipment carried with them in backpacks. The walk route begins near a carpark and then moves away from roads and other artificial structures. Cell phone reception is only sporadically available in the area. Sources of drinking water are available at both planned overnight campsites. Each participant carries a backpack containing their sleeping bag, food, water, clothing and personal equipment. Group equipment such as tarpaulins, ropes, a shovel and cooking equipment is distributed among group members to be carried in their backpacks. In addition, the leader carries a first aid kit, medical information for all group members, a printed weather forecast, a map, a compass, route notes, a mobile phone and a UHF radio. The walk route is planned to take the group across two mountain ranges and to conclude at a carpark about 40 km from the starting point. Terrain on the planned route includes flat and undulating trails through valleys and plains and steep rocky sections at higher elevations. Flora and fauna in the area include tree ferns, spiky shrubs, eucalyptus trees, kangaroos, wombats, possums, venomous snakes and numerous insects. Weather in this area during October typically incudes a temperature range of 4–28 °C with the possibility of strong winds and heavy rain.

The system of work in which a trek like this takes place includes several classes of interacting entities or elements. Actors are entities in this system that include participants, leaders and supervisors. Physical objects are entities such as items of camping equipment, route notes and trees. Cognitive objects are conceptual entities including trip objectives, activity standards and learning outcomes. Processes are entities such as compliance checking and route planning.

Each entity is an element within the system which interacts with other elements and is represented as a node on the system map. In order to understand the complexity of the system, the nature, number and scope of these entities is now considered, along with their relationships with each other.

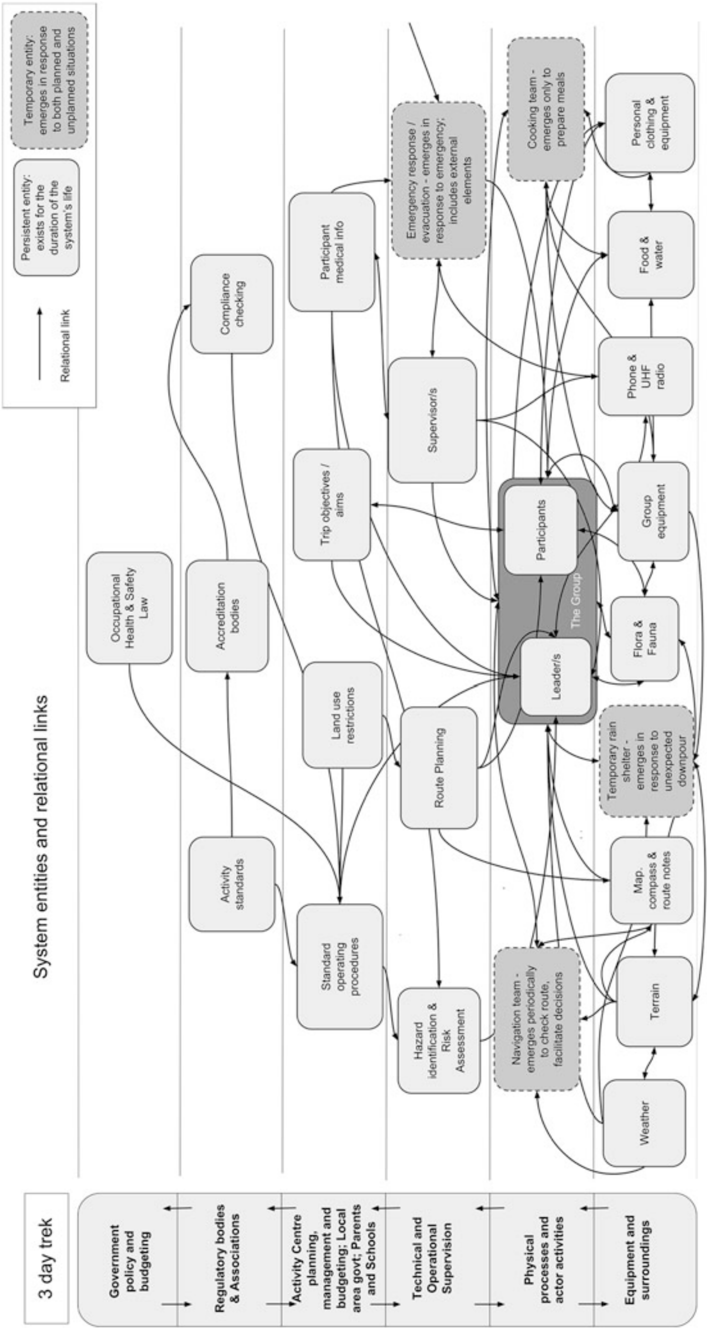

Fig. 1 System map for a three day trek

5 Analysis

The system map in Fig. 1 shows that this led outdoor activity program does indeed constitute a sociotechnical system. Social elements and subsystems (for example, leaders, participants and group), technical elements and subsystems (for example, group equipment; map, compass and route notes; standard operating procedures) are shown that interact with each other and with an external environment. This interaction is undertaken to achieve the program's stated goals. According to widely accepted definitions of sociotechnical systems, this simplistic led outdoor activity system is representative of what is normally considered a sociotechnical system.

Next, the analysis turns to the question of whether this sociotechnical system is complex in nature. In Table 1, the led outdoor activity system characteristics are examined against Cilliers' characteristics of complex systems [6].

As shown in Table 1, the simplistic 3 day trek led outdoor activity system can be viewed as displaying all of Cilliers' characteristics of complexity. Next, the apparent complexity of the led outdoor activity system under analysis is enhanced in order to further test and demonstrate the argument.

Table 1 Examination of three day trek led outdoor activity system against complexity criteria

Characteristics of complex systems	Examples of characteristic in case 1
Large number of elements	The nodes shown in Fig. 1 represent a number of entities: participants, group equipment, personal clothing and equipment are three examples of nodes that represent several elements. Importantly, these elements include human, environmental, technological, and non-technological artefacts
Dynamic interactions between elements	There are many dynamic interactions between elements. For example, the leader may check participants' navigation skills and, if required, teach how to navigate with map and compass; all group members interact dynamically with the weather, the terrain, flora and fauna and equipment. For example, participants may put on raincoats if it rains, apply insect repellent if mosquitos are biting or set up a rope to assist in crossing a fast-flowing stream
Elements interact with multiple other elements	Most elements shown in Fig. 1 interact with multiple other elements; group members interact with many other system elements; an evening meal can be produced for the group by one or several group members interacting with cooking equipment, the leader,

(continued)

Table 1 (continued)

Characteristics of complex systems	Examples of characteristic in case 1
	ingredients etc.; a navigation decision can be made quickly based on prior experience or multiple options can be considered; a temporary rain shelter can be constructed by many or few participants from many or few components
Interactions between elements are non-linear: small causes => large effects and vice versa	A few missing words in a weather report can lead to a multiple fatality incident (e.g. as in the Mangatepopo Gorge incident, see [5]; a chance close encounter with a soaring eagle on a mountain peak can trigger an epiphany
Information is received primarily from immediate neighbours	Aside from phone and radio communications the leader may have, most information enters the system from local sources
Recurrent loops in interactions	Cyclic processes of camping, cooking, packing and unpacking constitute recurrent loops; in outdoor education programs, learning occurs during the trip through recurrent loops of planning, experience and reflection
Complex systems are open systems: it is difficult to define the border and the system interacts with its environment	Elements in the physical environment such as rocks, trees, trail declines and inclines are continuously entering and exiting the boundary of this system as the group travels; the system continuously interacts dynamically with the physical environment, including weather, beyond the system boundary at any given moment; temporary entities emerge within the system boundary and then dissolve
Requires constant flow of energy to maintain system organisation	Navigation, group discussion, leadership decisions and action all represent energy flows that maintain system organisation. If any one component stops the overall activity cannot proceed effectively
A complex system's past is co-responsible for its present behaviour	Pre-trip preparation will determine resources available during the trip which will, in turn, constrain options available; interactions between participants may influence their relationship and the nature and outcome of subsequent interactions; physical features in the landscape where a program takes place long precede the program and shape the nature of the activity and procedures adopted
Each element in the system is ignorant of the behaviour of the system as a whole	The activity leader would be able to describe all of the parts and behaviours within a hiking shoe yet would not be able to describe all of the parts, interactions and behaviours that make up the hiking activity system

6 Other Cases

The three day trek described above can be considered to lie at the logistically simple end of the spectrum of common led outdoor activity programs. Common contexts for such a trip could be a Scouts or Guides camp, a bushwalk training trip for a tertiary outdoor education course or an outing for a community bushwalking club.

Two other examples of led outdoor activity program can be considered in order to gauge whether the findings for the three day trek are likely to be relevant across a range of common program types.

The first is a five day, multi activity outdoor education camp for secondary school students. Programs like this will typically run for multiple groups of students, each group accompanied by an outdoor leader and a school teacher. They may participate in bushwalking, paddling (raft or canoe) and roped activities (on a cliff or a challenge ropes course). They might camp for one or several nights in a bush campsite and perhaps stay at a residential camp for some nights. Groups may travel in minibuses to and from activities.

All of the system elements identified and mapped for the three day trek are likely to be present in the work system for the five day multi activity program. Moreover it is likely that the level of complexity will be increased due to a greater numbers of components and interactions involved. For example, the increased number of groups and activities adds many entities to the system, along with further required and situational interactions between a greater numbers of system elements. It therefore seems reasonable to conclude that the complexity of this system will equal or exceed that for the three day trek.

The second additional example is that of a ten day, remote area white water river expedition for a group of 8 participants and 2 leaders. The group will travel for four to six hours each day in rafts, kayaks or canoes, with slower flowing flat sections of river punctuated by varying grades of white-water rapids. The group will rest on the river bank for lunch and will establish campsites by the river each evening. Whilst on the river, all food and equipment will be fastened to luggage frames on rafts or stowed inside the hulls of canoes or kayaks.

As with the previous example, all of the system entities identified for the three day trek are present for the ten day river trip. Although the number of people in this system is lower, there is constant interaction between each of them, their boats and the ever changing sections of river. These factors and the highly dynamic and varied nature of the river itself mean that the number and duration of interactions between system elements is likely be higher than in the three day trek example.

7 Discussion

It is perhaps not surprising that the adoption of a complex systems theory approach to examining led outdoor recreation has received criticism. On the face of it, led outdoor activity systems may not appear to be similar in nature to the kinds of systems that are typically discussed in the complex sociotechnical systems literature. They can be logistically simple and afford an experience of simple living for participants. It may be that these appearances of simplicity lead practitioners to reject the suggestion that the system of work within which logistical and experiential simplicity occurs, can itself be complex. By looking beyond simplistic descriptions of led outdoor recreation, the case study presented in this article has provided evidence that led outdoor activity systems do in fact exhibit the characteristics associated with 'complex' and 'sociotechnical' systems. Even in the most simplistic of led outdoor recreation activities, the system and emergent behaviours are such that complexity is achieved.

This has significant implications, not only for safety in this domain, but also for other dimensions of work including productivity, program design, organisational design, work procedures, training and regulation. If the prevailing view of the system is linear and mechanistic, interventions to improve safety or productivity are likely to focus on system components, and are thus likely to be inappropriate and have little impact. Accident analysis will seek root causes associated with components (e.g. instructors, equipment) and recommend changes to those components as remedies. Initiatives to improve quality or productivity will focus on changing the characteristics of components or introducing new ones, with little consideration of the impacts on overall system functioning. In more conventional complex systems, these approaches to improving safety and efficiency are known to be ineffective. Viewing led outdoor activity systems through a 'simple, non-complex and non-sociotechnical' lens engenders inappropriate approaches for improving them.

By contrast, a systems view of the led outdoor activity work domain will encourage analysts of accidents to be alert for causal factors arising from patterns of interactions between elements within and across system levels. Managers will be encouraged to seek productivity improvements through changes to the relationships between system elements as well as in the elements themselves. Program designers will be more likely to explore multiple alternative program designs and options within programs to achieve aims. Regulatory systems will be designed in ways that support the flexibility and adaptability that a complex system requires for optimal performance. By viewing led outdoor activity systems through the same lenses as we do more traditional complex safety critical systems we will effectively expand our theoretical toolkit, providing the opportunities to gather richer data, to exercise more explanatory power, and ultimately to better optimise led outdoor activity systems.

It is hoped that the case study analysis presented acts as a call to arms for researchers in the area of led outdoor activities. In order to explore the benefits available from the application of systems thinking to the led outdoor activity domain, further research is required. A useful starting point would be to look at perceptions of the work system within the sector to build a picture of how it is understood by people in key roles such as program designers, managers and leaders. Studies examining how sociotechnical systems theory could be usefully applied to program design, staff training and achieving program aims could follow.

As an exploratory case study there are some limitations to acknowledge. The findings of the present study are limited by its hypothetical nature. Analysis of the typical programs studied here is sufficient to clearly identify that led outdoor activity programs do exhibit most or all of the established characteristics of complex, dynamic sociotechnical systems. However, the application of action research methods to system analyses of actual programs is likely to yield richer results including revealing how worker understanding of the system of work shapes program design and outcomes.

Whilst the opportunities of acknowledging the complex sociotechnical nature of led outdoor activity systems have been discussed, there are some potential pitfalls. For example, it is worth noting a key concern underlying some criticisms of applications of systems thinking to the domain of led outdoor activities (e.g. [11]). Here critics have expressed a fear that by attributing accident causation to factors other than the actions or omissions of leaders, those leaders may become more prone to abrogate their responsibilities for safety and want to blame 'the system' for their own failures. This concern has previously been raised in other domains. Dekker and Breakey [12], for example, cite Sharpe's [13] observations about similar concerns in the domain of patient safety [12, 13]. They advocate an approach to worker accountability that takes place within a 'Just Culture' where errors and violations by workers are treated by the organisation in a manner designed to constructively address harms, needs and causes. At the same time, deeper, systemic issues are identified and addressed. Dekker and Breakey [12] also tackles this issue, discussing how accountability is held regardless of whether a systems approach is taken or not as a result of aspects such as professionalism and personal involvement. Dekker also describes 2nd victim syndrome, whereby those involved in adverse events can experience similar levels of trauma as the victims themselves. A systems approach neither removes accountability nor prevents accountability from being held by those involved in incidents.

Future research initiatives may benefit the led outdoor activities sector by examining how approaches like Dekker's 'Just Culture' [12] might address concerns about abrogation of responsibility. Whilst systems theoretical approaches are supporting a growing body of research on safety, great potential exists to apply systems thinking to the analysis of productivity in the led outdoor activity domain.

8 Conclusion

This case study demonstrates that the system of work that supports even a logistically simple led outdoor activity program displays all of the hallmarks of complex sociotechnical systems. The consideration of two other typical outdoor program styles supports the proposition that most or all led outdoor activity programs occur within complex, dynamic sociotechnical systems. The findings therefore suggest that, not only is a sociotechnical systems approach warranted in this domain, it is required should research achieve its aims of optimising safety and efficiency.

This recognition provides analysts and designers with a firm theoretical foundation, previously missing from accident analyses, work design and system development in this domain. The improved objectivity and analytic tools afforded by this foundation offer unprecedented opportunity to enhance the safety, performance and resilience of led outdoor activity programs.

References

1. Brookes, A., Corkill QC, B., Smith, M.: Report to Trustees of the Sir Edmund Hillary Outdoor Pursuit Centre of New Zealand. Mangatepopo Gorge Incident 15 April 2008. Retrieved from http://www.hillaryoutdoors.co.nz/newsite/wp-content/uploads/2013/06/091015-IRT-OPC_-Report.pdf (2009)
2. White, P., Coroner: Inquest into the death of Kyle William Vassil. Retrieved from Melbourne. (2014) http://www.coronerscourt.vic.gov.au/resources/235cee6c-4ed6-4d07-b62c-c85097d669e3/kylewilliamvassil_066110.pdf
3. Salmon, P.M., Goode, N., Taylor, N., Lenné, M.G., Dallat, C.E., Finch, C.F.: Rasmussen's legacy in the great outdoors: a new incident reporting and learning system for led outdoor activities. Appl. Ergon. (In press). doi:http://dx.doi.org/10.1016/j.apergo.2015.07.017
4. Salmon, P.M., Goode, N., Lenné, M.G., Finch, C.F., Cassell, E.: Injury causation in the great outdoors: a systems analysis of led outdoor activity injury incidents. Accid. Anal. Prev. **63**, 111–120 (2014). doi:http://dx.doi.org/10.1016/j.aap.2013.10.019
5. Salmon, P.M., Cornelissen, M., Trotter, M.J.: Systems-based accident analysis methods: a comparison of Accimap, HFACS, and STAMP. Safety Sci. **50**(4), 1158–1170 (2012) doi: http://dx.doi.org/10.1016/j.ssci.2011.11.009
6. Cilliers, P.: Complexity and Postmodernism: Understanding Complex Systems. Routledge, London (1998)
7. Skyttner, L.: General Systems Theory: Problems, Perspectives, Practice. World Scientific (2005)
8. Vicente, K.J.: Cognitive work analysis: toward safe, productive, and healthy computer-based work. Mahwah, N.J.: Mahwah, N.J.: Lawrence Erlbaum Associates (1999)
9. Carayon, P.: Human factors of complex sociotechnical systems. Appl. Ergon. **37**(4), 525–535 (2006). doi:http://dx.doi.org/10.1016/j.apergo.2006.04.011
10. Goode, N., & Salmon, P. M. (2014a). The UPLOADS Project: the Systems Approach. Retrieved from http://uploadsproject.org/the-systems-approach/
11. Salmon, P., Williamson, A., Mitsopoulos-Rubens, P., Rudin-Brown, C., Lenne, M.: The role of human factors in led outdoor activity accidents: literature review and exploratory analysis. In: M. University Accident Research Centre (Ed.), (pp. 1–68). Australia: Monash University Accident Research Centre (2009)
12. Dekker, S.W.A., Breakey, H.: 'Just culture:' Improving safety by achieving substantive, procedural and restorative justice. Safety Sci. **85**, 187–193 (2016). doi:http://dx.doi.org/10.1016/j.ssci.2016.01.018
13. Sharpe, V.A.: Promoting patient safety: an ethical basis for policy deliberation. Hastings Center Report, 33(5), S3-20 21p. (2003)

Research on Energy Expenditure Detection Based on Three-Dimensional Acceleration

Qi Luo

Abstract The physical activity energy expenditure mainly refers to the part of the body energy which is used for muscle contraction to mechanical work. With the improvement of living standards, people's diet structure has changed enormously. Basing on it, the three-dimensional acceleration monitoring system to monitor the physical activity energy expenditure and daily actions is proposed in the paper. Hardware Design and The mechanism of accelerometer assessing movement energy were also proposed in the paper. The system is based on three-dimensional acceleration transducer MMA 7260QT and microprocessor MSP430F149.

Keywords Physical activity energy expenditure · MMA 7260QT · Three-dimensional acceleration · MSP430F149

1 Introduction

The physical activity energy expenditure mainly refers to the part of the body energy which is used for muscle contraction to mechanical work. With the improvement of living standards, people's diet structure has changed enormously. Many chronic diseases such as hypertension and diabetes mellitus have happened usually. One reason leading to this result is that people take fewer sports so that their energy expenditure is reduced. The detection of the physical activity energy expenditure is much important to forecast physical activity and improve movement way. In clinical medicine field, some diseases such as hyperthyroidism need to monitor the patient's energy expenditure. In the athletic training field, measuring

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physical activity is also need to improve athletes' training. In addition, the physical activity energy expenditure is also applied in nutrition and labor physiology fields [1–5].

Basing on it, the three-dimensional acceleration monitoring system to monitor the physical activity energy expenditure and daily actions is proposed in the paper. The system is based on three-dimensional acceleration transducer MMA 7260QT and microprocessor MSP430F149.

2 Three-Dimensional Acceleration Transducer MMA 7260QT

The MMA7260QT low cost capacitive micro machined accelerometer features signal conditioning, a 1-pole low pass filter, temperature compensation and g-Select which allows for the selection among 4 sensitivities. Zero-g offset full scale span and filter cut-off are factory set and require no external devices. Includes a Sleep Mode that makes it ideal for handheld battery powered electronics.

Features as follows:

- Selectable Sensitivity (1.5 g/2 g/4 g/6 g)
- Low Current Consumption: 500 μA
- Sleep Mode: 3 μA
- Low Voltage Operation: 2.2–3.6 V
- 6 × 6 × 1.45 mm QFN
- High Sensitivity (800 mV/g @ 1.5 g)
- Fast Turn On Time
- Integral Signal Conditioning with Low Pass Filter
- Robust Design, High Shocks Survivability
- Pb-Free Terminations
- Environmentally Preferred Package
- Low Cost.

Typical Applications as follows:

- HDD MP3 Player: Freefall Detection
- Laptop PC: Freefall Detection, Anti-Theft
- Cell Phone: Image Stability, Text Scroll, Motion Dialing, E-Compass
- Pedometer: Motion Sensing
- PDA: Text Scroll
- Navigation and Dead Reckoning: E-Compass Tilt Compensation
- Gaming: Tilt and Motion Sensing, Event Recorder
- Robotics: Motion Sensing.

Figure 1 is Pin Connections and Fig. 2 is Simplified Accelerometer Functional Block Diagram.

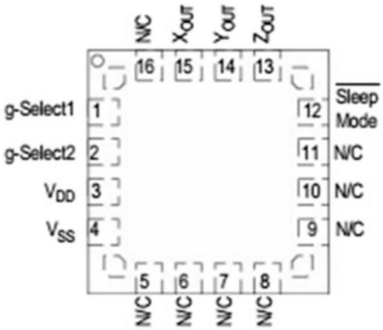

Fig. 1 Pin connections

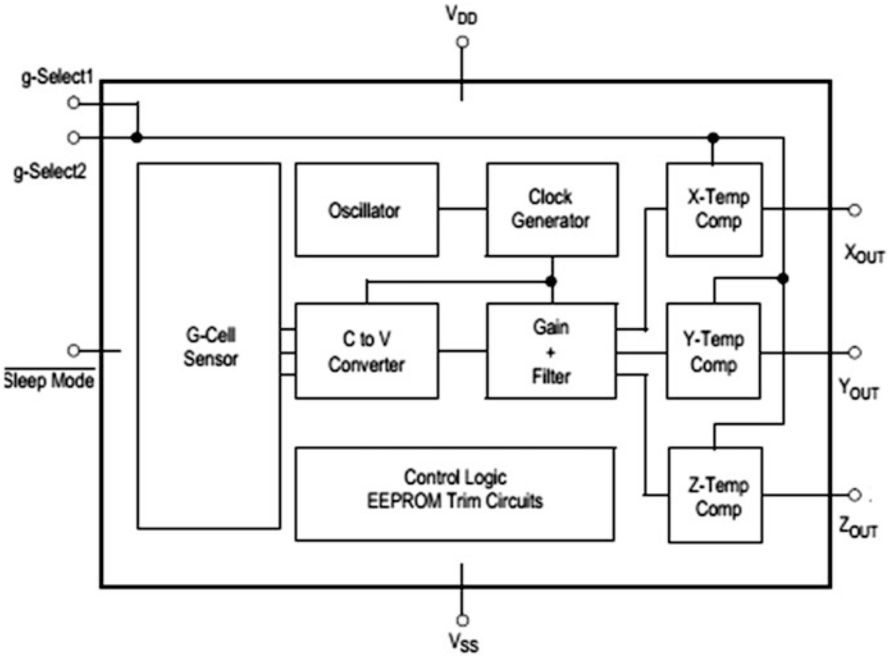

Fig. 2 Simplified accelerometer functional block diagram

3 MSP430F149

The Texas Instruments MSP430 family of ultralow-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low power modes is optimized to achieve extended battery life in portable measurement applications. The device

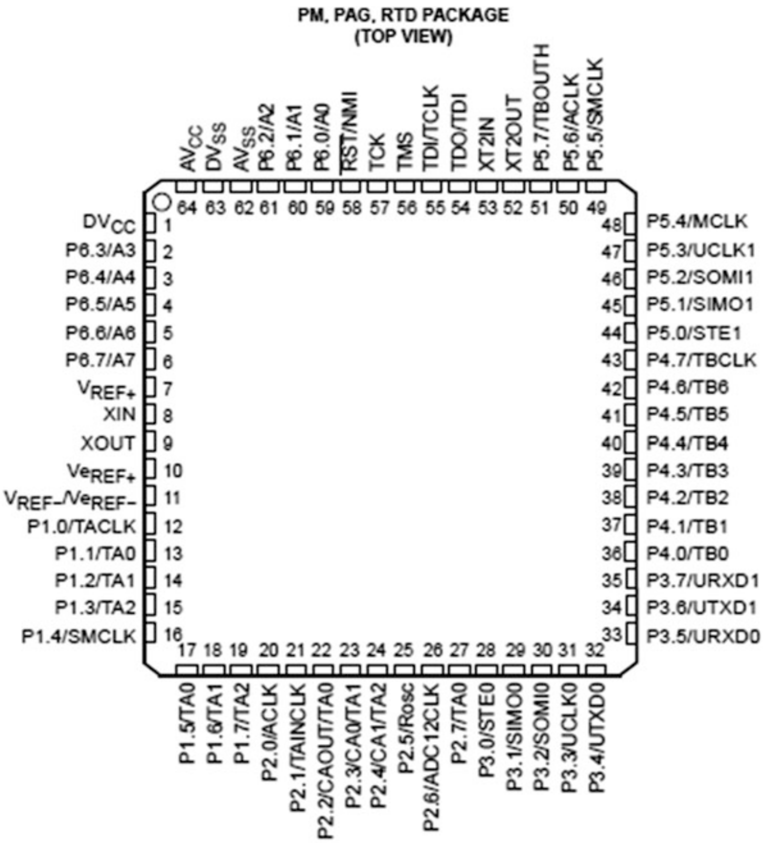

Fig. 3 Pin connections

features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that attribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6 μs.

The MSP430x13x and the MSP430x14x(1) series are microcontroller configurations with two built-in 16-bit timers, a fast 12-bit A/D converter (not implemented on the MSP430F14x1 devices), one or two universal serial synchronous/asynchronous communication interfaces (USART), and 48 I/O pins.

Typical applications include sensor systems that capture analog signals, convert them to digital values, and process and transmit the data to a host system. The timers make the configurations ideal for industrial control applications such as ripple counters, digital motor control, EE-meters, hand-held meters, etc. The hardware multiplier enhances the performance and offers a broad code and hardware-compatible family solution. Figure 3 is MSP430F149 Pin Connections.

4 The Mechanism that Accelerometer Assess Energy of Movement

Speed acceleration is the rate of change that the velocity of the object varies over time, is physical quantities that describe the size and direction of the velocity of the object. Acceleration sensor is an electronic device that can measure acceleration.

There are two kinds of Accelerometer: one is the angular accelerometer, is improved by gyro (angular velocity sensor). Another is linear accelerometer.

Acceleration of the movement of objects is a space vector. On the one hand, if we want to accurately understand the motion state of objects, we must measure the component on its three axes. On the other hand, in the status of cases that we don't know the motion of an object in advance, we only use multi-dimensional acceleration sensor to detect the corresponding acceleration signal. At the same time, with the rapid development of science and technology, the traditional one-dimensional acceleration sensor has been unable to satisfy increasing high sensing information requirements in the measurement, control and information technology and other areas [6, 7].

There are many different kinds of accelerometers. From the measured principle, it can be divided into piezoelectric effect type, capacitive type, inductive type, strain type, piezoresistive type and surface acoustic wave type, etc. From the measured dimensions, it can be divided into one-dimensional model, individual two-dimensional model, a handful of three dimensional type [8].

The human body movements not only have dynamic characteristics such as physical activity, as well as static features such as the weight load. However, all forms of exercise can eventually be attributed to muscle contraction and energy consumption caused by heat dissipation and physical work. When we do exercise, the sugar, fat and protein oxidation in our body do reaction with oxygen in our body, produce carbon dioxide and water, releasing energy at the same time. More exercise, oxygen consumption will be increased, and within certain limits, the oxygen consumption of the subjects of the muscles is proportional to the power of muscle per unit time, and cardiac output caused by muscle motion is proportional to oxygen consumption. Therefore, we can use the oxygen consumption of unit weight and unit time to represent the energy of movement [9].

Bouten and Sauren [10], in a three-dimensional acceleration sensor research, used three-dimensional acceleration sensor placed perpendicular by three one-dimensional piezoresistive sensor as well as its supporting data processing software to measure the body exercise.

The results are as follows: in internal reliability test of the repetitive experiments and instrument, the offset and sensitivity of three-dimension acceleration sensor in each measurement direction are the same.

And three-dimension acceleration sensor has excellent linear relationship between output and energy consumption ($r = 0.95, p < 0.001$).

Whether in the high intensity and low intensity experiment, the inconsistencies between output and energy consumption of three-dimension acceleration sensor are smaller than one-dimensional acceleration sensor.

Relative to the one-dimensional acceleration sensor, the superiority of three-dimension acceleration sensor is very obvious, and its output value is closer to the objective true value.

At present, we use the following formulas 5–1 to calculate energy of sports,

$$EE_{tot} = EE_{act} + SMR \tag{1}$$

We can use respiratory gas analyzer to measure the amount of the oxygen consumption and carbon dioxide generation, and calculate the total energy consumption of body EE_{tot}. And we can measure AMR (Sleeping Metabolic Rate) of subjects in quiet sleep in a respiratory chamber.

Bouten and Westerterp [11] etc. considered that the effect of heat EE_{diet} generated after dinner should be considered. So the exercises in the experiment are arranged in 1.5 h or 2 h after dinner, as a result, EE_{diet} can be rule out. Thus, $EE_{tot} = EE_{act} + SMR$, the final EE_{act} by this method can be considered the true value of body motion.

We can worn the exercise measuring device based on three-dimension acceleration on the rear waist, the output of accelerometer are been amplified, filtered and shaped through data processing apparatus, then integral of absolute value taking 30 s as intervals can be calculated and obtain output AO_X, AO_Y, AO_Z in X, Y, Z axis.

$$AO_X = \int_0^t |a_x| dt \tag{2}$$

$$AO_y = \int_0^t |a_y| dt \tag{3}$$

$$AO_z = \int_0^t |a_z| dt \tag{4}$$

$$AO_{tot} = AO_X + AO_Y + AO_Z \tag{5}$$

Since AO_X, AO_{tot}, EE_{act}

$$EE_{act} = -0.176 + 0.085\, AO_X \tag{6}$$

$$EE_{act} = 0.104 + 0.023\, AO_{tot} \tag{7}$$

where, EE_{act} denote the energy consumption, unit: (J/min/kg), AO denote the accelerometer output units: times/min.

The conversion relationship between Joule and one thousand Ka Lula, as formulas 5–8

$$1\,\mathrm{kcal} = 4184\,\mathrm{J} \tag{8}$$

Large number of experiments proves that, the absolute value of body acceleration versus time integral and energy or oxygen consumption is a linear relationship. And provides a specific theoretical basis for the accelerometer assess human's movement.

In this study, three-dimensional accelerometer used to output AO_X, the linear relationship model of energy consumption EE_{act} used to calculate the energy consumption of the person what during exercise.

5 Hardware Design

Energy Expenditure Detection based on Three-dimensional acceleration is composed of portable measuring device and computer data processing device. Portable measuring device consists by the sensor signal acquisition and processing controller is respectively linked together with the acceleration sensor, temperature sensor, pulse sensor, and the wireless signal transmission module. Computer data processing device that connected by the wireless consists of computer and wireless signal receiving module that connected to the computer, portable movement measuring device and computer data processing device connected to each other through wireless, Fig. 4 shows the specifics.

In the above technical solution, the portable measuring device provided with large capacity memory, keyboard and LCD monitor, USB interface. They are linked together with the data port of the sensor signal acquisition and processing controller's. Three-dimensional acceleration sensor built into the portable measuring device, pulse sensor and the temperature sensor is provided in the bottom plate of the portable measuring device.

Computer data processing device management the data written to the database firstly (the data through wireless receive or USB receive), respectively to analysis energy consumption, Motion gesture, health consultants, etc., and combined with pulse, temperature to do a health state of motion analysis and processing, provide recommendations of health exercise, for example, recommended type of movement, time, etc.

This design has simple structure, convenient operation, low cost testing, and low power consumption. By fast data processing, it can provide rationalization guidance of health exercise for individuals. Physical activity energy monitor through measuring the waveform of three-dimensional acceleration, identify the type of human body exercise, to set up a motion energy consumption mathematical model and

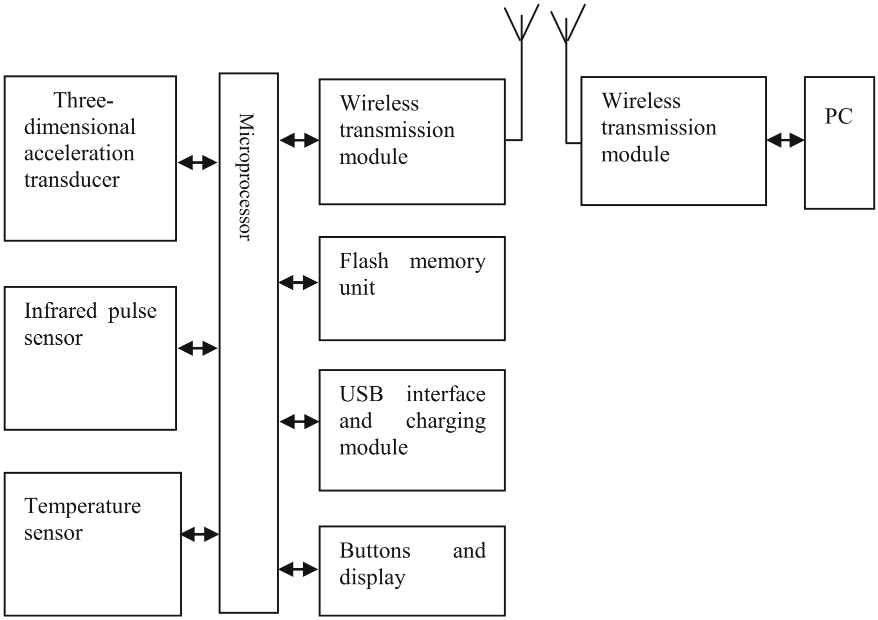

Fig. 4 The structure of energy expenditure detection based on three-dimensional acceleration

basic relations of human motion energy consumption and motion type, and acceleration, pulse, temperature, height, age, gender, etc., it can automatically select the corresponding mathematical model to carry out real time monitoring and to calculate the energy consumption.

6 Conclusion

Basing on it, the three-dimensional acceleration monitoring system to monitor the physical activity energy expenditure and daily actions is proposed in the paper. Hardware Design and The mechanism of accelerometer assessing movement energy were also proposed in the paper. The system is based on three-dimensional acceleration transducer MMA 7260QT and microprocessor MSP430F149.

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References

1. Grace, T.W.: J. Am. Coll. Health[J]. **45**(6), 243–251 (1997)
2. Davies, J., McCrae, B.P., Frank, J., et al.: Identifying male college students' perceived health needs, barriers to seeking help, and recommendations to help men adopt healthier lifestyles. J. Am. Coll. Health [J] **48**(6), 259–267 (2000)
3. Ware, Jr JE , Snow, K.K, Kosinski, M. et al.: SF-36 Health Survey Manual and Interpretation Guide [J]. New England Medical Center the Health Institute, pp. 1–12. Boston (1993)
4. McFarlane, A.H., Neale, K.A., Norman, G.R., et al.: Methodological issuesin developing a scale to measure social support [J]. Schizophr. Bull. **7**, 90–100 (1981)
5. Levine, H.M., Basham, R.B., Sarason, B.R.: Assessing social support: the social support questionnaire [J]. J. Pers. Soc. Psychol. **44**(1), 127–139 (1983)
6. Kerem, Shuval, Eyal, Weissblueth, Mayer, Brezis, et al.: Individual and socioecological correlates of physical activity among Arab and Jewish college students in Israel [J]. J. Phys. Act. Health **6**(3), 306–309 (2009)
7. Nuala M. Byrne, Jarrod D. Meerkin, Raija Laukkanen, et al. Weight Loss Strategies for Obese Adults:Personalized Weight Management Program Vs [J]. Standard Care, 2006
8. Loney, Tom, Standage, Martyn, Thompson, Dylan, et al.: Objectively assessed physical activity: which is right for public health [J]. J. Phys. Act. Health **8**, 62–70 (2011)
9. Carter, S.M., Rychetnik, L., Dietetics, PGradDip Lloyd, B et al.: Evidence, ethics, and values: a framework for health promotion [J]. Am. J. Public Health **101**(3), 465 (2011)
10. Bouten, C.V.C., Sauren, A.A.H.J.: Effects of placement and orientation of body-fixed accelerometers on the assessment of energy expenditure during walking [J]. Med. Biol. Eng. Comput. **35**, 50–56 (1997)
11. Bouten, C.V., Westerterp, K.R.: Assessment of energy expenditure for physical activity using a triaxial accelerometer [J]. Med. Sci. Sports Exerc. **26**(12), 1516–1523 (1994)

Part III
Health, Injury and Accidents

Strategy for Prevention and Control of Occupational Injuries Sports Related in a Public Utility Company

Emilio Cadavid and Luz M. Sáenz

Abstract This article presents Empresas Públicas de Medellín's (EPM) strategy for the prevention and control of occupational sports injuries. The strategy works alongside EPM's physical activity program to increase the overall quality of life of the Company's employees, and is based on Colombian legislation that stated in 2012 that occupational accidents should also include those that occur when recreational, sporting and cultural activities are carried out on behalf of, or while representing an employer. The article presents concepts, policies and activities related to the practice of sports at EPM, and how these are aligned with the systemic approach of ergonomics. The article also looks at how EPM has managed to reduce these kinds of accidents, and how the strategy has strengthened actions for prevention and health promotion in an occupational context. In doing so, it has ratified the Company's Business Commitment with the wellbeing and overall quality of life of its employees.

Keywords Occupational sports accident · Prevention, promotion and control · Wellbeing programs in workplace · Physical screening · Sports medical examination

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Empresas Públicas de Medellín (EPM) is a public utility company that provides electricity, natural gas, water supply, basic sanitation, waste management, information technology and communication services that meet the very highest international standards of quality in Medellín, Colombia. Organized as a "state-owned, industrial and commercial enterprise". With 6000 employees and 10.583 family members who are beneficiaries of a set of services for health and safety within a framework of prevention and promotion as a strategy to improve quality of life.

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1 Introduction

Participating in different types of physical activity (recreational, sporting and cultural) is nowadays considered a key element in all workplace “wellbeing” programs.

In terms of prevention, Ergonomics has an essential role to play in the workplace, with the application of its principles helping to establish conditions for the welfare, health and safety of employees. According to the approach taken by the WHO, actions that create healthy working environments boost business productivity, competitiveness and sustainability, while their implementation, which is extended to employees’ families, has the possibility of becoming part of the strategies for the quality of life of the family group.

This example of a business commitment by EPM proposes an action model for physical activity as a prevention and health promotion strategy. Within a framework, the model outlines definitions and concepts that relate to physical activity, physical exercise, sport and the benefits of exercise. It establishes a proposal for the relationship between ergonomics and the three levels of public health actions for prevention, showing that physical exercise has a role to play in all three.

In this model, physical activity at EPM encompasses different components: sport (internal and external competition); recreation; and participation in physical exercise (working out at the gym). Through a physical infrastructure and an interdisciplinary group of professionals, these components support the model’s actions, which in turn meet the objectives that outline the benefits of physical activity in relation to performance in the workplace and the maintenance of a healthy lifestyle habits.

Since 2000, this model has led to the start-up of 18 gyms in several regional campuses throughout Antioquia and offices located in the city of Medellín. The increase in gym usage is proof that a culture of physical exercise at EPM is getting stronger. Teams have been set up to participate in a diverse range of sports such as athletics, basketball, cycling, swimming, football/soccer, chess, billiards, volleyball; and recreational activities such as fishing, hiking and water activities.

Physical Activity as a prevention and promotion strategy has led to the creation of a culture of employee self-care that has been extended to the family environment. It has also led to the set-up of teams participating in a range of high-performance sports. Empresas Públicas de Medellín has realized the need to develop corresponding actions for preventing and managing occupational sports accidents. This article outlines such actions and how they have been developed as a model for the wellbeing and safety of employees. The article also examines the systemic vision of ergonomics/human factors, and how it takes into account the sportsperson (individual), the staging (context) and the sport (activity) within a framework of Colombian legislation and, most importantly, the consolidation of a culture of care [1].

2 Framework

2.1 *Colombian Legislation Relating to Occupational Risk*

Colombian legislation has existing laws relating to occupational health that include, amongst others, provisions for occupational accidents. The legislation includes:

Work-Related Accidents. Article 3 of Law 1562 (2012) (through which the occupational risk system is modified, and other provisions relating to occupational health are enacted) [2], states that:

An occupational accident is a sudden and unforeseen occurrence arising out of or during the course of work, and which results in one or more workers suffering a personal injury, a functional or psychiatric disorder, disability or death.

An occupational accident also occurs whilst carrying out instructions from an employer, or from a contractor during the execution of work under their authority, even if this work is carried out at a different location or outside regular hours of work.

An occupational accident also occurs during the transfer of workers or contractors from their place of residence to their place of work, or vice versa, and when the method of transport is provided by the employer.

An occupational accident also occurs when one or more workers are engaged in trade union duties.

Likewise, an occupational accident also occurs during recreational, sporting or cultural activities, when it is carried out on behalf of, or while representing the employer, or a client company during the execution of temporary services.

Decree 1072 (2015) Organization of the Occupational Health and Safety Management System.

Article 2.2.4.6.8. Employer Obligations. The employer is obliged to protect the health and safety of their employees, in accordance with the established norms.

As part of the Occupational Health and Safety Management System (SG-SST) at the company, the employer has, amongst others, the following obligations to its employees:

Occupational Risk Prevention and Promotion: The employer must implement and develop preventative activities related to occupational accidents and illnesses, and health promotion activities as part of the Occupational Health and Safety Management System (SG-SST), in accordance with existing legislation [3].

The Company's Risk Management Unit and the Occupational Risk Administrator (ARL) work together to coordinate the Occupational Health Program for the occupational health and safety management system, under provision of Law 1562.

2.2 *Company Regulations*

Decree 1928, Dated March 2014. Business Rules Handbook for Sporting and Recreational Activities. A handbook was created with the objective of defining certain business rules and standardizing the administration and development process of sporting and recreational activities. The handbook includes: terms and definitions related to these activities; promotional and outreach actions; information on the activities that are offered; registration information; requirements for participation; and information relating to permits and cautions. The Welfare Management Unit is responsible for these actions [4].

2.3 Definitions Associated with Sport and Occupational Sports Accidents

Sports Accident. An event that happens suddenly during a sporting activity, and which can threaten the health of a participating individual or group. It is deemed an occupational accident if it occurs during EPM's programmed activities for sporting groups representing the Company, and will be dealt with by the Occupational Risk Insurer.

Physical Aptitude. An individual's ability to carry out day-to-day tasks with the objective of improving their quality of life.

Competition. A game that is based on meeting a specific objective, and which results in a classification of participants, the pronouncement of winners and some form of recognition for those that excel, and. By its nature, it is a tool to check progress of regular training.

Informed Consent. A procedure that ensures that an individual has voluntarily expressed their intention to participate in a sporting or recreational activity organized by the company (as an additional benefit). Once the individual has understood the information presented to them regarding the objectives, benefits, possible risks and alternatives, and their rights and responsibilities, an informed consent is signed.

Sport. This term covers a range of activities carried out according to a set of rules and practiced for pleasure or on a competitive basis. Sporting activities usually consist of physical activities performed by a team or individuals, and subject to some kind of institutional framework (a sporting body, for example) [5].

It is a category of specialized "physical activity" that requires physical training, and is generally carried out at high intensity. It is guided by a series of rules or codes and performed within a certain space or area (playing field, pitch, board, table, etc.).

Training. A planned and complex practice whereby workloads are progressively increased to stimulate the physiological processes of body compensation. It can be tuned to meet different physical capacities and qualities, and has the objective of promoting and strengthening athletic performance.

Medical Sports Evaluation. A process, carried out by a Specialist Doctor in Sports Medicine, which assesses the general state of health and in particular the physical aptitude of those that wish to participate in sports and recreational programs. Information is recorded in a Medical History.

Representative Sports Groups at EPM (Teams). Sporting and/or cultural teams made up of employees and selected by the Welfare Management Unit to represent EPM in a sporting discipline or cultural activity.

Inactive Individuals. Inactive individuals are those unable to participate in recreational and sports activities because (a) they are deemed by a specialist sports medicine doctor and/or EPM's ARL to be medically ineligible or incapacitated; (b) they are on vacation or leave of absence; (c) they are temporarily suspended for disciplinary reasons.

Screening. A process that evaluates the basal conditions of strength, flexibility and endurance, as well as basic health information (weight, size, heart rate and blood pressure) and history of chronic and musculoskeletal disease. Information is recorded in a format established by EPM and is performed by health workers and sports professionals.

3 Sports and Accidents, Rates at EPM

Physical Activity as a Prevention and Promotion Strategy has been developed through an action model at EPM since 2002. Its aim is to encourage the effective use of spare time; to improve the working environment and the sense of belonging within the Company; to offer a space for family integration; and to develop healthy lifestyle habits. All of these factors can lead to a better quality of life [6]. This action model comprises various components: sport; recreation; and taking part in physical exercise (working out at the gym).

For each of these components, the Company offers a number of different activities. According to the analysis of professionals and experts at the Welfare Management Unit, certain regulation has been defined that includes: the different areas for participation; target participants; eligibility requirements; number of participants; frequency (length of commitment); associated costs; and penalties for non-attendance. The criteria are in accordance with Decree 1928 dated March 2014: Business rules handbook for sporting and recreational activities [4].

In particular, sports practice at EPM includes individual and team activities that take part in internal and external tournaments i.e. competitions between different

Table 1 Sports teams authorized by EPM

Sporting activity	
Chess	Swimming
Athletics	Spinning
Women's basketball	Women's softball
Men's basketball	Men's softball
Billiard	Table tennis
Bowling	Tennis
Cycling	*Tejo*
Football/soccer	Women's volleyball
Indoor football/soccer	Men's volleyball

Table 2 Groups participating in recreational and sporting activities at EPM and the behavior of occupational sporting accidents

Physical activity groups EPM (recreational, internal tournaments, representative groups)									
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of participating employees	2987	2727	3152	3222	3848	3871	**Law 1562 and Informed Consent creation**		
Number of incapacitating accidents	54	51	55	47	47	35			
Number of incapacity days	1462	1140	1007	992	1192	698			
Sports teams (groups representing EPM)									
Number of participating employees	226	231	244	235	236	249	258	256	267
Number of incapacitating accidents	11	10	18	16	9	13	8	10	9
Number of incapacity Days	187	100	282	455	167	140	157	139	112

campuses within the Company, or between other companies and entities that are able to field teams. These teams currently comprise some 270 employees. Table 1 shows the different sports teams authorized by EPM.

Accidents can occur as a consequence of taking part in these activities. This can result in a period of incapacity that varies according to the seriousness of the injury, and which can also affect the productivity of the area in which the employee works. This type of accident is called an occupational sports accident (ATD, in Spanish). In accordance with existing Colombian legislation through the Occupational Risk Administrator (ARL), this can entail a series of financial obligations for the employer that guarantees the wellbeing of the employee during their recuperation period.

Table 2 shows two groups of employees who participated in recreational and sporting activities at EPM (in teams and in tournaments and recreational groups) and the behavior of sporting accidents from 2007 to 2015. During this period, accidents that occurred in these groups were considered Occupational Accidents only due to the fact that they were sponsored by EPM. In terms of incapacity days, the figures signify high costs for the company.

After Law 1562 was enacted in 2012 as part of Colombian legislation governing occupational risk, an Occupational Sports Accident was only recognized when it occurred during training and competitions whilst representing EPM (teams), which significantly reduced the exposed population.

The table shows a reduction in frequency (number of accidents) and severity (number of incapacity days), a trend that became far more significant from 2012 following the introduction of “Informed Consent” for internal tournaments and recreational activities. This excluded Occupational Sporting Accidents (ATD) from “occupational accidents”, and with it, all associated legal implications.

4 Prevention and Control of Occupational Injuries Sports Related at EPM

Among its objectives, EPM aims to guarantee the integrity of its employees through the management of occupational risk and wellbeing, and within a framework of improving overall quality of life. A model for the prevention and control of occupational sports accidents has been developed that works alongside a Physical Activity program as a Strategy for Prevention and Promotion. This model includes a series of actions aligned with the systemic approach of ergonomics, a discipline that seeks to understand the interaction between Activity and the elements that comprise the Individual-Technology-Context system. The sportsperson (the individual), the sport (the activity) and the sports locations (the context) are considered variables within the framework of this model.

Table 3 Activities for the prevention and control of occupational sports accidents in relation to the sportsperson

Activity	Target group
Screening	All employees registered for sporting or recreational activities at the company
Sports medical examination	All employees that belong to representative groups at the company
Training in physical fitness and warming-up	Training instructors responsible for the different sporting, recreational and cultural groups
Meeting of sports team coaches	Coaches of representative groups, members of EPM's Sports Group (administrators and training instructors), personnel at the Occupational Risk Administrator (ARL) and Universities that send Physical Education participants to the Company. Meeting to include: regulations, follow-up activities and accident prevention
Team training sessions	All employees that belong to representative groups at the company; training in specific sports techniques and physical fitness
Team workshops	All employees that belong to representative groups at the company. To include: Strength testing, flexibility and physical fitness—specifically Wells test, core muscles, long jump, shoulder mobility. Also workshops in: strength and power, concentration and precision
Team conferences	All employees that belong to representative groups at the company. To include: Specific sports techniques, anxiety management
Pre-season games	All employees that belong to representative groups at the company, especially those that participate in high impact sports
Sports sanctions	Players reported to be in breach of rules

These actions include the monitoring of accident rates at the company; a constant analysis of criteria related to sport, such as checking the physical ability of employees through an examination of individuals' conditions and risk factors; a regular evaluation of the locations for practicing sports; a review of regulations; and training for referees and delegates.

Sports competitors are put forward for the Epidemiological Monitoring System for Musculoskeletal Disorders (MSDs), and are included in the Company's overall target to reduce serious injuries.

Tables 3, 4 and 5 describe the activities that are developed for each variable, and their respective target groups.

Table 4 Activities for the prevention and control of occupational sports accidents in relation to the sport

Activity	Target group
Revision of rules, Recreational-sporting activities	All employees registered for sporting or recreational activities at the company
Meeting of team coaches	Coaches of representative groups. Meetings for start-up, regulations, follow-up activities and accident prevention
Team training regulation	Coaches of representative sports groups at the company, members of EPM's Sports Group (administrators and training instructors), personnel at the Occupational Risk Administrator (ARL) and Universities that send Physical Education participants to the Company; training in other areas, including: rules and team commitments
Overseeing matches and team training	EPM's Sports Group (administrators and training instructors), methodology (instructors qualified in supervision of training plans or different sports teams, and Occupational Risk). Training in behavior and compliance of conditions for sportspeople and coaches
Meeting of suppliers	Contract suppliers, availability of locations, security conditions
Accident prevention meetings	Occupational Risk Administrator, specialist in sports medicine. The analysis of reporting procedures in the event of an occupational sports accident
Apprentice training	Physical education apprentices (participants). To include: the rules of fair play
Training in reporting procedures for occupational sports accidents	Training instructors
Specialist seminars	Delegates of internal tournaments. To include: Regulation, fair play, and prevention of sporting accidents
Meeting of disciplinary panels	Panel Members: comprising a trial expert, an employee representative, a company representative and a contractor (supplier of services). To analyze regulations, payroll, sanctions and acquittals
Sporting sanctions	Players reported to be in breach of rules (Sanctions and acquittals outlined in sports regulations)

Table 5 Activities for the prevention and control of occupational sports accidents in relation to the sport

Activity	Target group
Meeting for suppliers	Contract suppliers, availability of locations, security conditions
Inspection visit of locations	Occupational risk administrator, sports medicine specialist

5 Results of the Strategy—Conclusions

Even though participating in physical activity has been crucial for the wellbeing of employees in a work context and their overall quality of life, it has also led to the emergence of sports accidents, which in some cases have been considered occupational accidents. Given the effects this had on employee performance and productivity, a specialized and/or careful program was required to manage and control this trend.

The absence of any kind of regulation concerning accidents that occurred during physical activity carried out within companies meant high numbers of incapacity days, and increased costs for the business.

Since 2000, actions geared to the control of sports accidents have been created, and with satisfactory results. This can be seen in lower levels of accident frequency and severity.

The definition of occupational accidents (as per Colombian occupational legislation related to occupational risks, enacted in 2012) to include those that occur when recreational, sporting and cultural activities are carried out on behalf of, or while representing an employer, contributed to the strengthening of actions for the prevention and control of occupational sporting accidents and the clarity in managing information for both the company and those employees that participate in physical activity.

EPM, through the actions of Human Resources Management, the Quality of Life Board and the units under their control: the Risk Management Unit, the Wellbeing Management Unit, and the regulations set out in Decree 1928 of March 2014: Business rules handbook for sporting and recreational activities, has strengthened the development of a model for the prevention and control of occupational sports accidents. This includes a series of actions aligned with the systemic approach of ergonomics that takes into account the sportsperson, the sport and the locations for its practice.

The figures on occupational sports accidents in terms of frequency (number of incapacitating accidents) and severity (number of incapacity days) show a downward trend that became far more significant from 2012.

Three milestones have been achieved within the activities of prevention and control of Occupational Sporting Accidents. From the start, "sports screening" has defined the suitability of participants; secondly, a "specialized sports medical examination" has established not only an individual's sporting limits, but also identified those features that can improve performance in physical activity and daily life; finally, the initiation of "informed consent" based on Law 1562 that led to a gradual increase in participant self-care.

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References

1. Cadavid, E., Sáenz, L.M.: Physical activity as a strategy for prevention and health promotion in the occupational context: an example of corporate engagement. In: Karwowski, W., Ahram, K. (eds.) Manufacturing Procedia 6th International Conference on Applied Human Factors and Ergonomics, pp. 2760–2767. Elsevier, Las Vegas, USA (2015)
2. Congreso de la República de Colombia: Ley 1562. Santafé de Bogotá, Colombia (2012)
3. Ministerio del Trabajo, República de Colombia: Decreto Único Reglamentario del Sector Trabajo. http://decreto1072.co/. Bogotá, Colombia (2015)
4. Empresas Públicas de Medellín: Manual Reglas de Negocio de Actividades Deportivas y Recreativas-V4. Medellín, Colombia (2014)
5. Organización Mundial de la salud: Recomendaciones mundiales sobre actividad física para la salud. Ginebra, Suiza (2010)
6. Cadavid, E: La Actividad Física, Un Compromiso Empresarial. Revista EPM, pp. 56–59 (2011)

Identifying Human Factors Mismatches in Amusement Ride Containment Failure

Paula Stenzler, Holly Handley and Kathryn Woodcock

Abstract Amusement rides are a familiar and popular form of immersive entertainment. Millions of guests visit theme parks, amusement parks and carnivals for recreation every year with low incidence of injury. However, the rare event of rider ejection or extraction from restraints on a ride could have serious or fatal outcomes. This study examined human factors characteristics of these rare events to identify the nature of rider separations in relation to these patterns. Physical mismatch of patron size and the containment system was significantly associated with type of separation, with large patrons not secured and small size or cognitive disability associated with falls and ejections. This information will aid ride designers in selection of an effective containment system.

Keywords Human factors · Amusement rides · Safety

1 Introduction

Amusement rides are a familiar and popular form of immersive entertainment. Millions of guests visit theme parks, amusement parks and carnivals for recreation every year with low incidence of injury. However, the rare event of rider ejection or extraction from restraints on a ride can have serious or fatal outcomes. Among the causal suppositions often discussed in the industry are a mismatch between cognitive development and anatomical size, wherein, ridership eligibility intended to filter cognitive readiness is established by guest height; and thrill-seeking patrons who actively use devices intended and designed to be experienced passively. The purpose of this study is to examine human factors characteristics of these rare events to identify the nature of rider separations in relation to these patterns.

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2 Background

The industry is largely self-regulating and maintains one of the highest safety records for recreational activities according to several sources [1–3]. Ride accidents are a rare occurrence [4]. However, one occurrence will produce an adverse response from the public extending well beyond the accident venue, rippling through the entire amusement industry. It is estimated that approximately 1.4 billion safe ride experiences are produced a year as a result of an estimated 315 million patrons visiting over 357 fixed-site amusement parks in the United States [3].

Nearly all containment failures associated with amusement ride restraint and containment systems fall into two categories: (1) young riders unable to comprehend the severe consequences and risks associated with their behavior, and (2) patrons that purposefully engage in unsafe behavior [2]. While small children are likely candidates for falls, ejections and mis-positioning in amusement rider restraint and containment systems (R^2CS), at the other end of the spectrum, adult patrons with unique somatotypes (body shape) are candidates as well.

Individuals without a certain level of cognitive reasoning cannot comprehend the risks associated with their actions, thus extra measures are required to prevent willful patron extraction. Ridership eligibility based on height rather than on a holistic anthropometric association enable some extractions. Child patrons may have excess free movement space due to lack of correlation between their girth and height. These children may be able to defeat restraint and containment systems by slipping out of the restraint by maneuvering legs enough to push out the top of the restraint.

Under widely used industry standards, the designer-engineer performs a ride analysis which includes among other elements a containment analysis [5]. During the containment analysis, the designer-engineer considers the nature of the ride and determines the desired age requirement, which is converted to a minimum height requirement using anthropometric tables referenced in the standard. During the containment analysis, the designer-engineer considers the nature of the ride and determines the desired age requirement, which is converted to a minimum height requirement using anthropometric tables referenced in the standard. The containment system is selected according to the ride acceleration profile under the applicable design standard. During the containment analysis, the designer-engineer may note that more conservative restraints or more restrictive height eligibility or both are required, due to specific characteristics of the ride that increase the severity of potential harm. For instance, analysis of a mild ride at a high elevation would consider that any rider separation could lead to a serious injury due to a subsequent fall. While standards refer to preventing unintended contact by protecting a reach envelope around large (i.e., 95th percentile adult male) riders along the ride path, they do not specify the clearance requirements to prevent passage of smaller riders.

Falls and ejections have occurred due to containment designs that could not adequately accommodate unique patron anthropometry. A 31 year old woman too large to ride was fatally ejected from a ride at a Dublin fair [6]. With a bilateral leg amputation, a 29 year old male lacked the manual gripping strength to remain secured in a roller coaster and was fatally ejected [6, 7]. Twelve years earlier, a 37 year old man had been ejected from the same coaster due to his large size, and another large man was killed due to ejection on another installation of this coaster because his restraint could not be securely fastened [7, 8]. In another incident, after slipping out of the harness, a 12 year old boy fell 129 feet to his death on a free-fall "drop tower" ride [8]. These rare but tragic cases indicate that the ride analysis may fail to identify the risk associated with unique patron anthropometry when establishing restraint and containment systems design criteria.

Cognitive science—studies of the mind, awareness, decision-making, difficulty and related issues—is becoming an important part of the field of design [9]. Some containment failures associated with defeating restraint systems involved very young riders that were unable to comprehend the severe consequences and risks associated with their actions due to limited cognitive development. In 13 cases analyzed by the U.S. Consumer Product Safety Commission (CPSC) [2], the riders were between two and eight years of age and were able to access the restraint locking mechanism and opened it. In these cases, the patrons were unable to recognize the hazards associated with releasing the restraint locking mechanism.

Patron behavior is a major factor in restraint and containment injuries. There are several reasons why patrons engage in unsafe behavior when experiencing rides and are in an unfamiliar setting. Just as parents influence children's behavior and social development, so does the interaction with peers and friends. The attitude of peer groups is highly influential and is closely linked to peer-acceptance. Acceptance of peers is so compelling that it causes a child to discard parental values and acceptable behaviors and engage in risk taking activities [10]. Woodcock noted that making social connections and attaining sensory enhancement provided plausible explanations for many rider errors observed on carnival midways, along with inaccurate mental models and physical slips [11].

Lack of cognitive development is not the only cause of risk-taking activities. The CPSC examined two cases in which two adult males deliberately extracted their legs out from under the restraint and placed them on the seat in order to ride unencumbered by the restraint. In this case, the men were able to recognize the risks associated with defeating the restraint but still elected to engage in this behavior [2].

Men are said have a higher desire for sensation-seeking experiences than women and this desire is at its height during the teens years to early twenties [12]. Although associated with risky behavior, Zuckerman argued that high-sensation-seeking is a normal personality trait [13].

Thus, past reported analysis has pointed toward physical size and shape, misunderstanding, and thrill seeking as primary mechanisms for failure of the R^2CS in severe and fatal injuries. However, these were based on limited data such as individual or small samples of cases. This study undertook to compile and analyze a comprehensive dataset in relation to these factors and determine how they contribute to the type of failure that occurs.

3 Method

The attractions industry maintains an active safety program, but detailed data are not widely released to the public and could not be obtained for the purpose of this study. Because this type of adverse event attracts media attention, reports of events occurring globally are collected in several secondary sources that archive reports of amusement ride injuries. The primary sources used in the data polling are affiliated with non-profit, government, public service, advocacy, regulatory, and trade organizations and are listed in Table 1.

Records were stripped of individually identifying description prior to analysis. Each record was coded to record characteristics of the event and outcome, characteristics of the ride, and characteristics of the injured rider. Table 2 identifies the variables and values extracted from source data.

"Patron limitations" included both large and small anthropometric characteristics and cognitive disabilities. Reports mentioning petite or too-large size, and cognitive disability were tabulated as "physical limitations". For analysis based on "diminished capacity", data for children aged 12 or under were combined with reports mentioning cognitive disabilities of any age. Behaviour was considered "compliant" unless one of the non-compliant behaviors was mentioned. Two failure modes were used for classification. Ejection/fall refers to cases where the rider was properly secured in the containment system at the start of the ride cycle but completely separated from the ride vehicle, and "not-secured" refers to patrons that were not secured properly in the containment system due to size, e.g. restraint did not

Table 1 Data sources

Organization	Website
RideAccidents.com	www.rideaccidents.com
Amusement safety organization	www.amusementsafety.com
National electronic injury surveillance system	www.CPSC.gov
National safety council	www.nsc.org
Saferparks	www.saferparks.org
UK health and safety executive	www.hse.gov.uk
Outdoor amusement business association	www.oaba.org
Various regulatory agencies referenced in other documents	Agency website

Table 2 Variables and values used in analysis

Event variables	Ride variables	Rider variables
Type of failure	Ride type	Age of injured person
Injury severity	Restraint type	Gender of injured person
	Seating configuration	Large or small size
		Cognitive disability
		Antecedent behavior

contact the rider at the proper anatomical location or rider was out of position, for instance, with both legs on the same side of the pommel.

4 Results

4.1 Extracted Dataset

The resulting dataset contained 109 events producing 112 injuries, of which 32 % were fatal. Although 2002–2007 represents 30 % of the time span analysed, 41 % of reported failures were in that period. In the preceding seven years, there were 24 failures reported, and in the following seven years, there were 41 failures.

4.2 Type of Ride Involved

Four ride types accounted for 80 % of R^2CS failures. Revolving-spinning rides were involved with 38 % of events, 19 % involved roller coasters, 13 % kiddie rides/coasters, and 10 % vertical wheels with the remainder a variety of ride types (Fig. 1). Ride type was not a significant predictor of failure type (P = 0.148, Fischer's Exact Test FET).

Rides with no restraint or shared restraint comprised over 59 % of the events (Fig. 2) while multi-rider seating configuration was involved in 51 % (Fig. 3).

4.3 Patron Characteristics

Age. Age was reported for 103 injuries. Riders aged 21 or under sustained 74 % of the injuries. Within that group, 41 % were 0–10, 33 % were 11–21. Adults over 21 sustained 26 % of the injuries (Fig. 4).

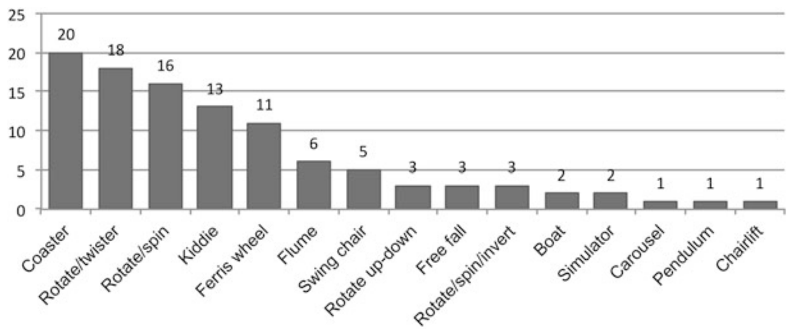

Fig. 1 R^2CS failures by ride type

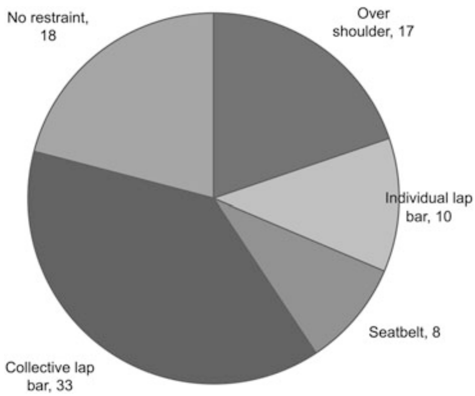

Fig. 2 Restraint type in R^2CS failure events

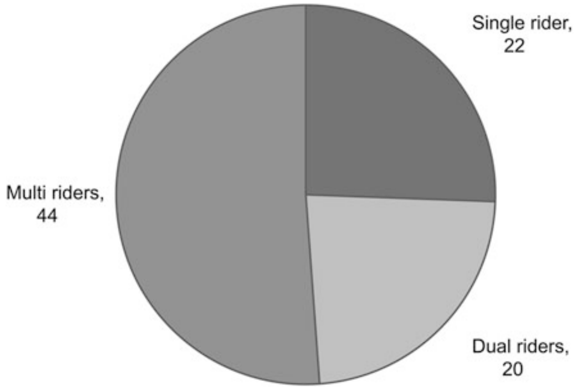

Fig. 3 Seating configuration in R^2CS failure events

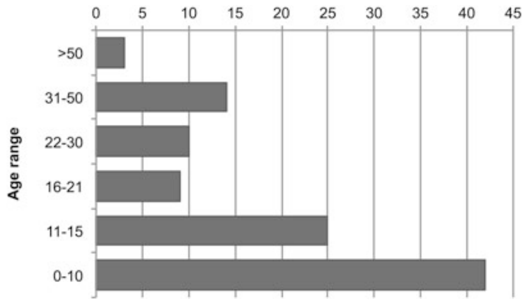

Fig. 4 Age distribution of riders injured in R^2CS failure events

Gender. Females sustained 51 % of the injuries over the 20-year entire period of analysis.

Patron Limitations. The classification of "patron limitations" was applied to cases where the rider was described as being of too-large or petite size, or cognitive disability. Size was mentioned in 11 reports, while cognitive disabilities were

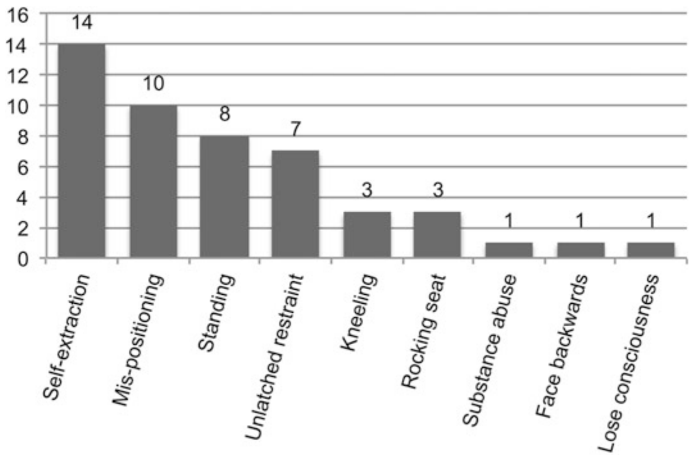

Fig. 5 Reported non-compliant behaviour antecedents of fall/ejection

mentioned in 2 reports. There was no association of cognitive level and injury severity (p = 0.665, FET).

Behavior. Consistent with other studies [4, 14], most reports (57 %) did not describe antecedents to the failure event. Where the patron's prior actions were documented, standing (8/48) and mispositioning or self-extracting from the seat (14/48) were the most common behaviors preceding the occurrence of ejection or fall (Fig. 5). The source material mentioned non-compliant behavior in 56.7 % of failures.

4.4 Association of Patron Characteristics and Failure Mode

Associated Limitations. The type of failure mode (not secured or ejection/fall) was highly associated with patron limitations of too-large size, petite size, reported cognitive disability, or undetermined limitation. Patrons with cognitive disability or of petite size were all ejections and falls (comprising 2 and 3 % of ejections/falls respectively), while all patrons described as too large were not secured, comprising 53 % of all failures involving patrons not secured ($p = 0.000$, FET).

Diminished Cognitive Capacity. There was also a significant association between cognitive ability and failure mode. Considering those with cognitive disabilities and ages 13 and younger as having diminished cognitive capacity, not-secured failure modes affected a higher percentage of diminished-capacity patrons (79 %) compared to ejection/fall (43 %) ($X^2_{1\text{d.f.}} = 6.34$, $p = 0.012$).

4.5 Association of Patron Behavior and Failure Mode

Patron behavior type and failure mode shows a significant association (p = 0.000, FET) (Table 3). A higher proportion of ejection/fall failures occurred with normal behavior (57 %) compared to not-secured failure mode where 87 % entailed a form of non-approved behavior.

4.6 Association of Restraint and Seating Configuration and Failure Mode

Restraint type was described in 86 reports also describing failure mode. No significant association exists between restraint type and failure mode (p = 0.177, FET) (Table 4).

There is no significant association between seating configuration and failure mode (p = 0.445, FET) (Table 5).

4.7 Logistic Model of Failure Mode

Individually, limited cognitive capacity, and anthropometric limitation appeared to contribute to the type of R^2CS failure, therefore a logistic regression model was

Table 3 Association of behavior and failure mode

Behavior	Ejection/fall	Not secured
"Compliant": No unapproved behavior mentioned	45 (57.0 %)	2 (13.3 %)
Misposition	5 (6.3 %)	8 (53.3 %)
Unlatched restraint/interfered with mechanism	7 (8.9 %)	0 (.0 %)
Standing	17 (21.5 %)	5 (33.3 %)
Other unapproved behavior	5 (6.3 %)	0 (0.0 %)
All	79 (100 %)	15 (100 %)

Table 4 Association of restraint type and failure mode

Restraint Type	Ejection/Fall	Not secured	
Over the shoulder	15 (20.5 %)	2 (15.4 %)	17
Individual lap bar	7 (9.6 %)	3 (23.1 %)	10
Seatbelt	5 (6.8 %)	3 (23.1 %)	8
Collective lap bar	30 (41.1 %)	3 (23.1 %)	33
No restraint	16 (21.9 %)	2 (15.4 %)	18
Total	73 (100 %)	13 (100 %)	86

Table 5 Association of seating configuration and failure mode

Restraint type	Ejection/fall	Not secured
Single rider	19 (25.3 %)	3 (27.3 %)
Dual riders	16 (21.3 %)	4 (36.4 %)
Multi riders	40 (53.3 %)	4 (36.4 %)
Total	75 (100 %)	11 (100 %)

Table 6 Logistic regression model predicting failure mode

Predictor	Odds ratio	B	p
Anthropometric mismatch	9.538	2.255	0.010
Diminished capacity	2.636	0.969	0.224
Non-compliant behavior-mispositioning	36.337	3.593	0.001
Non-compliant behavior—standing and other	6.565	1.882	0.072

Notes Anthropometric mismatch comprises failures involving restraint type of over-the-shoulder and a rider with cognitive disability or too large or petite size. Diminished capacity includes 13 and younger and cases described as having cognitive disability. Non-compliant behavior includes all cases of mispositioning, unlatching or interfering with restraint mechanisms, standing, or other behavior described as non-compliant. In this table, mispositioning and other non-compliant behavior were treated as separate variables, each compared with normal behavior

constructed combining these three predictor variables and the outcome of not-secured or ejection/fall failure. Each predictor was created as a binary variable of presence or absence of the factor. The model (Table 6) is significant ($X^2_{4d.f.} = 30.46$, $p = 0.000$, $R^2_{C\&S} = 0.284$, $R^2_{Nagelkerke} = 0.494$).

5 Discussion

Three variables associated with failure mode were individual differences between riders, specifically anthropometric limitation, cognitive capacity, and behavior. Variables describing the type of ride, type of seat, and type of restraint did not predict type of failure mode. While riders' individual differences predicted type of failure, this analysis did not examine whether those individual differences predicted greater involvement in restraint failure in general, because there is no data source to provide exposure data broken down by these characteristics. In other words, riders with these characteristics may not be overrepresented in restraint failure events when total ride exposure is taken into account.

A not-secured failure mode is associated with anthropometric mismatch and non-compliant behaviour, particularly mispositioning. In contrast, ejection and fall were associated with normal behaviour. Ride vehicles with multi-rider seats and shared restraints or no restraints comprised the majority of failure events. These ride characteristics tended to be falls and ejection failure modes rather than not-secured cases, although the failure mode differences fell short of significance.

Roller coasters and spinning rides comprised the largest category of ride types involved. Although this may reflect only their relative prevalence among rides in operation, the simple majority of occurrences may justify prioritizing these ride types as a starting point to look for ways to mitigate rider separation.

Contrary to literature and popular assumptions about risk-taking and thrill seeking, the data do not establish an overrepresentation of males among riders involved in R^2CS failure-related injuries. This may indicate that males with this tendency seek thrills in other types of recreation such as mountain climbing, stock car driving, extreme sports and other competitive activities. It may also gender differences in disposition to report when injuries are sustained, causing female reports to proliferate.

Similarly, while diminished capacity (due to young age or disability) is often speculated as a hazard for ride exposure, and did predict type of failure mode on its own, it was not associated with non-compliant behavior, and it fell far short of the predictive value of physical and behavioral differences in the multivariate logistic regression model of failure type. Consistent with previously cited findings [15], this suggests that uniform restrictions based on disability are not warranted.

While injuries per year have increased during the analysis period, the incidence cannot be interpreted without data on exposure. For instance, the attendance at North American theme parks and attractions has been increasing at approximately 4 % per year for several years.

6 Conclusions and Recommendations

Extremes of size should be considered in choice of rider containment systems, as too large riders may not be adequately secured and petite riders may be able to reposition within secured restraints. Even over-the-shoulder restraints can allow riders with exceptional dimensions to be unsecured or ejected, and designer-engineers should consider vulnerable extremes of body size and shape. Non-compliant behaviours should be anticipated in the design of restraint and containment systems to avoid configurations that enable patrons to stand or defeat restraints when severe injury could be sustained.

References

1. International Association of Amusement Parks and Attractions: Amusement ride safety: Safety by the numbers. http://www.iaapa.org/safety-and-advocacy/safety/amusement-ride-safety
2. Smith, T.P.: Human factors review of restraint failures on mobile amusement rides. Project report, US Consumer Product Safety Commission, Washington, DC (2005)

3. National Safety Council: Fixed-site Amusement Ride Injury Survey, 2013 Update. Author, Alexandria, VA (2015)
4. Woodcock, K.: Amusement ride injury data in the United States. Saf. Sci. **62**, 466–474 (2014)
5. ASTM International: Standard Practice for Design of Amusement Rides and Devices F2291-15. Author, West Conshohocken, PA (2015)
6. Amusement Safety Organization: 2011 Accidents and news. http://www.amusementsafety.org/safety_news_11.asp
7. RideAccidents.com. http://www.rideaccidents.com/2011.html
8. RideAccidents.com. http://www.rideaccidents.com/1999.html
9. Dreyfus, H., Tilley, A.R., Wilcox, S.B.: The Measure of Man and Woman: Human Factors in Design, Rev edn. Wiley, New York, NY (2002)
10. Bradbury, K.: Peer influences on risk-taking in middle childhood. University of Vermont, Master's Thesis. http://scholar.lib.vt.edu/thesis/available/etd-051199094949/ (1998)
11. Woodcock, K.: Rider errors and amusement ride safety: observation at three carnival midways. Accid. Anal. Prev. **39**, 390–397 (2007)
12. Zuckerman, M., Buchsbaum, M.S., Murphy, D.L.: Sensation seeking and its biological correlates. Psychol. Bull. **88**, 187–214 (1980)
13. Munsey, C.: Frisky, but more risky. Am. Psychol. Assoc. **37**(7), 40 (2006)
14. Woodcock, K.: Content analysis of 100 consecutive media reports of amusement ride accidents. Accid. Anal. Prev. **40**, 89–96 (2008)
15. Woodcock, K.: Determining participation eligibility for amusement attractions. Procedia Manuf. **3**, 5389–5396 (2015)

Application of Functional Movement Screen to the Evaluation of Youth's Physical Health

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Abstract In order to improve the physical health level, the test and evaluation of physical health for youth emerged with the goal of comprehensive determination of healthy situation of youngsters, and more importantly of orientational function to guide them scientific way of physical exercises. Current physical health test typically focus on the performance of physical fitness test (PFT), such as strength, endurance, flexibility …, without considering the evaluation of basic human movement pattern and posture alignment. Functional Movement Screen (FMS) is a simple and convenience test designed following basic movement principles of the natural human growth and development, which can make a systematic and effective evaluation on our basic movement abilities, like mobility, stability and symmetry. As the fundamental of functional training system and the classic test of body functional movement, FMS is widely applied in physical therapy and strength and conditioning area, and has good reliability and validity. This research selected randomly 120 middle school students as the subjects. 7 functional movement tests and 3 exclusive tests were tested to evaluate the basic body functional pattern. And standard physical fitness tests were tested in the following day. The results of FMS show that the total average score of FMS is 14.98. Although at a low level, it is not below 14 points which standards a higher risk of potential injury. The boy's average total score is 15.12, and the girl's is 14.83. There is no significant difference between different sex. Many basic functional movement problems like the poor stability, bilaterally asymmetry of body strength, eversion of the knees and obviously unparallel shoulders are largely observed during the tests. The research

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reveals: (1) the basic functional movement ability of youth is low, and correcting training is needed for them to move well first before improving the physical fitness performance; (2) The low correlation between FMS and PFT indicates that movement quality and physical performance are two independent abilities and could not be replaced by each other; (3) It is suggested that functional movement ability should be tested besides standard physical fitness ability to avoid potential injures and further improve movement and posture of youth.

Keywords Functional movement · Adolescent · Physical fitness · Movement and posture ability · Functional movement screen

1 Introduction

Adolescents Physical Fitness has recently been highly concerned as a major issue of national concerns by the Chinese government. It shows that, according to a national survey on adolescent physical fitness and other local surveys by researchers, morphological growth (e.g. height, body weight, etc.) of adolescent in the country was seeing an increasing growth in the past two decades, while physical quality index like strength, speed and endurance decreased continuously. Therefore, poor physical quality becomes the key factor responsible for the overall decline in adolescent physical fitness. Physical quality presents itself in physical ability in sports, as a reflection of comprehensive performance of human organs. Innovative development in theories and methods of physical fitness training provide valuable references on the solution of adolescent physical fitness problems [1].

There has been unanimous agreement on the importance and effectiveness of functional movement training in the fields of rehabilitation and competitive sports. It was appealed by experts that basic training on functional movement should be based on Use and Disuse Theory, followed by special skill development. Currently, training on motion function became an important research area for adolescents.

Theoretically, adolescence is the prime time for physical growth with the presence of critical stages for physical quality development [2]. Improvement in core stability and functional movement brings them flexibility, stability and coordination, which facilitates the manifestation of physical qualities. However, unequivocal relationship has not been built between core stability, functional movement and physical quality in researches at present. Based on adolescent physical growth situation, skill acceptance degree and psychological characteristics, this work explored the correlation between the test results of Functional Movement Screen by Gray Cook and Chinese National Student Physical Health Standard (50 m run, sit-ups (for girls only), pull-ups (for boys only), long jump, sit and reach, 800 m run (for girls only), 1000 m run (for boys only)).

2 Research Object and Method

2.1 Subject

Experimental object consists of 110 grade two students (62 boys and 48 girls) of Guanshan junior middle school, Wuhan City, Hubei Province. Thereinto, experimental group consists of 32 boys and 23 girls; control group of 30 boys and 25 girls. The whole experimental object has no professional sports experience, physical or mental disease. For the experimental object, the physical examination is normal; there is no lack of the basic sports experience caused by major trunk injury or surgery in the last year; there is no injury pain in the last month. The experimental object regularly participates in the physical education activities every week. There is no any extracurricular sports activity. Before experiment, the potential risks are informed to test object and the parents with written form. After that, formal consent is signed.

The research is supported by Culture and Sports Bureau of Hongshan District, Wuhan City, Hubei Province; The School Committee of Guanshan Middle School, Wuhan City, Hubei Province; Exercise Collaborative Innovation Center for Intervention and Health Promoting of Hubei Province (Table 1).

2.2 Experimental Method

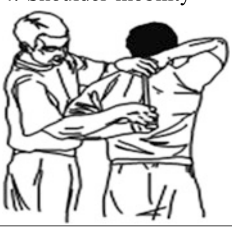
Functional Movement Screen (FMS). Based on the law of human growth and development, Cook formulates a functional movement screen consisting of 7 functional movements and 3 excluding tests, for functional evaluation of basic movement model. These movements are considered the basis of complicated movements in daily activities and sports. Functional movement screen is designed to find the weakness of basic movements of human, as well as in flexibility, stability, pliability and symmetry. As a classic testing method for movement, it is regarded as the basis of movement training system, with high reliability and validity. Table 2 shows the rating criteria in detail. Two video cameras are used to record the testing at sagittal and frontal directions, respectively, to maintain the rating consistency. Rating is performed by a specialist in functional movement training on the basis of video files according to the criteria.

National Students' Physical Health Standard. While implementing the National Students' Physical Health Standard, schools usually choose the following basic test indexes, which are with high reliability and efficiency, to reflect teenagers' physical quality, so does this study: 1. 50 m running, whose function is to

Table 1 Description statistics of the test subjects

	Age	Height (cm)	Weight (kg)
Subjects	14.62 ± 3.12	168.0 ± 12.1	62.33 ± 21.5

Table 2 Scoring criteria of functional movement screen (FMS)

Movement	Score	Scoring criteria
1. Deep squat	0	Feeling hurt during test
	1	Additional conditions: heel on a 2 × 6 inches plate 1. Tibia and upper torso are not parallel 2. Femur not below horizontal 3. Knees are not aligned over feet 4. Lumbar flexion noted
	2	Additional conditions: heel on a 2 × 6 inches plate 1. Upper torso is parallel with tibia or toward vertical 2. Femur below horizontal 3. Knees aligned over feet 4. Dowel aligned over feet
	3	1. Upper torso is parallel with tibia or toward vertical 2. Femur below horizontal 3. Knees aligned over feet 4. Dowel aligned over feet
2. Hurdle step	0	Feeling hurt during test
	1	1. Contact w/foot and hurdle 2. Loss of balance at any time
	2	1. Alignment is lost between hips, knees and ankles 2. Movement in lumbar spine 3. Dowel and hurdle do not remain parallel
	3	1. The hip, knees and ankles remain aligned in the sagittal plane 2. Minimal movement in lumbar spine 3. Dowel and hurdle remain parallel
3. In-line lunge	0	Feeling hurt during test
	1	1. Loss of balance at any time
	2	1. Movement noted in torso 2. Feet do not remain in sagittal plane 3. Knee does not touch behind heel of front foot
	3	1. Minimal to no torso movement 2. Feet remain in sagittal plane on the 2 × 6 inches plate 3. Knee touches 2 × 6 inches plate. Behind the heel of front foot
4. Shoulder mobility	0	1. Feeling hurt during test 2. Feeling hurt during impingement test
	1	Fists fall greater than one and a half hand lengths
	2	Fists should be within one and a half hand lengths
	3	Fists should be within one hand length

(continued)

Table 2 (continued)

Movement	Score	Scoring criteria
5. Active straight leg raise 	0	Feeling hurt during test
	1	Malleoli resides below mid-patella
	2	Malleoli resides between mid-thigh and mid-patella
	3	Malleoli resides between mid thigh and ASIS
6. Trunk stability push up 	0	1. Feeling hurt during test 2. Feeling hurt during impingement test
	1	1. Male unable to perform 1 rep w/hands in line w/chin 2. Females unable to perform 1 rep w/thumbs in line w/thumbs in line w/clavicle
	2	1. Males perform 1 repetition w/thumbs in line with chin 2. Females perform 1 rep w/thumbs in line w/clavicle
	3	1. Males perform 1 repetition with the thumbs above head 2. Females perform 1 rep w/thumbs in line with the chin
7. Rotary stability 	0	1. Feeling hurt during test 2. Feeling hurt during impingement test
	1	Unable to perform diagonal repetitions
	2	1. Performs 1 diagonal rep while keeping torso parallel to board 2. Knee and elbow touch in line with the board
	3	1. Performs 1 unilateral rep while keeping torso parallel to board 2. Knee and elbow touch in line w/the board

test students' speed, agility and neural circuit flexibility. 2. 80 m running (for girls) or 1000 m running (for boys), works to test students' endurance quality, especially functions of the cardiovascular-respiratory system and muscular endurance. 3. Standing long jump, used to test the explosive power of students' legs and their body coordination ability. 4. Pull-up (for boys). It is a method to test muscular strength of students' arms. 5. Sit and reach. This exercise is done to test the scope that students' body parts, like trunk, waist and hip can reach in a static state. Its main goal is to reflect the extensibility and elasticity of joints, ligaments and muscle of those body parts. 6. Sit-up (for girls), aims to test students' abdominal muscular endurance. For all indexes, the scoring criteria will strictly obey the National Students' Physical Health Standard.

Data Analysis and Process. Descriptive and inferential statistics were performed. Pearson's product-moment correlations were used to evaluate relationships between test variables: (a) functional movement screen (FMS); (b) national student physical health standard.

3 Research Result and Analysis

3.1 Research Result

According to the study, there is a strong correlation between functional movement screen and the testing results of teenagers' physical quality, which is clearly shown in Table 3. Which indicated the strong correlation between functional movement ability of youth and the testing results of teenagers' physical quality. Taking 50 m running as an example; its testing results indicate a positive correlation with active straight leg raise, which is the same as the testing results of sit and reach. And the testing results of standing long jump also have a positive correlation with hurdle jumps (left). However, the testing results of 800 m running (for girls) are associated with deep knee bend and trunk stable front support negatively, contrary to 1 min sit-up (for girls) and 1 min pull-up (for boys) whose testing results relate to trunk stable front support negatively. Yet, no correlation is found between 1000 m running and motor function screening.

3.2 Analysis and Discussion

According to conception of World Health Organization (WHO), youth means the stage between children and adult. Due to the differences between the physiological development and actual age, the exact stage is difficult to judge [3]. Therefore, WHO suggests that girls age 12–18 and boys age 14–18 years old. As the backbone of the country for the future development and the hope of national revival, the young generation should be reflecting the power and beauty of Chinese nation. However, at the moment of China's economy developing into a world power, with the declining of youth's physical fitness and health worldwide, our nation's physical fitness level of adolescent dropped seriously. According to the "No. 46 document" from the central committee of the communist party in China, enhancing youth's physical activity and improving their physical fitness and health is an important strategic mission of China. In recent years, in order to promote the standard of physical fitness and health of adolescent, the Chinese Ministry of Education, the General Administration of Sport of China and China's Communist Youth League issued many guidance documents gradually, like "Implement the Sunshine Sports Movements for Millions of National Students." "Strengthen Youth Sports to Enhance Adolescent Health". Besides, with the purpose of appealing to young people to increase their physical activity time and load, various movements such as "Million of Student Sunshine Sports Winter Long-distance Running Events", "the Enlarged Class rest for Physical Activity" and "Excise one hour a day" movements have been launched nationwide. Because of widely publicized

Table 3 Summary of correlations between functional movement screen and national students' physical health standard

	50 m run	Long jump	Sit and reach	800 m run (girls)	1000 m run (boys)	Sit-ups (girls)	Pull-ups (boys)
Deep squat	−0.106	0.230	0.307	−0.755	0.019	0.744	−0.309
Hurdle step (left)	−0.341	0.468	0.225	−0.100	0.056	0.381	0.102
Hurdle step (right)	0.047	0.043	0.267	0.367	0.191	0.086	−0.323
In-line lunge (left)	0.050	0.066	0.021	0.078	0.008	0.243	0.208
In-line lunge (right)	−0.051	0.103	0.219	0.136	−0.154	0.009	−0.394
Shoulder stability (left)	0.200	0.128	−0.183	0.374	−0.094	−0.492	0.024
Shoulder stability (right)	0.038	0.117	0.085	−0.306	−0.240	0.070	−0.173
Active straight leg raise (left)	0.382	0.211	0.380	0.422	0.277	−0.004	0.090
Active straight leg raise (right)	0.404	0.157	0.423	0.208	0.250	0.036	−0.312
Trunk stability push up	−0.261	0.245	0.118	−0.429	−0.083	0.795	0.688
Rotary stability (left)	−0.012	0.041	−0.152	0.254	−0.046	0.391	0.408
Rotary stability (right)	0.091	0.091	−0.064	0.266	0.123	0.286	0.357

acknowledgment and avocations for aerobic exercise, the situation of physical fitness and health of primary and secondary students have been improved preliminary. But the high incidence of sports injury, the passive participation of youth and low benefit-cost ratio of physical activity involvement made the present situation not very optimistic.

Based on basic action law of human normal growth, Cook designed FMS (Functional Movement Screen) of 7 functional movements and 3 exclusion tests to evaluate functional state of basic movement mode. These movements were considered as the basis of more complicated movement mode in daily activities and sports [4]. FMS aims at finding weak links of basic human action and checking the deficiency of body flexibility, stability, flexibility and symmetry. With high reliability and validity, FMS is a classical test method of functional movement and the footstone of training system. Main movements consist of deep squat, front support, hurdle posture, straight lunges, shoulder flexibility, straight leg raise and rotational stability (left and right). Table 2 showed the score standard of each movement. The movements were recorded by two cameras from vertical and frontal planes to keep the consistency of the scores. After that, video files were uniformly scored by one functional movement training experts based on evaluation standards.

As the subbase of functional movements, these 7 basic movements stand for basic movement mode of human body, uniting the whole sports events. FMS is a method of evaluate free movement without deficiency, restriction, compensation and asymmetry. In FMS process, the test scores were analyzed to know physical conditions of athletes, thus formulating the program for the next training. With simple operation and quantized results, FMS demonstrated that movement mode was the key of basic body function. FMS led to finding problems and track training, thus complementing corrective training of body recovery [5]. Therefore, FMS is a scientific test method consisting of 7 movements, detailed score illustration and abundant movement base for corrective training.

Research result show that: functional movements are significantly associated with adolescent physical fitness, as indicated in Table 3. 50 m running, body antireflection in sitting position is related to active straight knee leg around on both sides of the action pattern; standing long jump and hurdle frame step left movement patterns are significantly correlated; 800 m running (female) and squat, trunk stability bent support related; 1 min sit-up (female) is correlated significantly to squat and stability of the trunk bent bracing; pull ups in a minute to (male) and stability of trunk bent support are significantly correlated. These correlations indicate that the test methods taken are consistent with the action patterns used in the subjects' body. Active straight knee leg action looks very simple, and the essence is to evaluate to human body in the lower extremities without ability to straddle the load state.

Also, it has the ability to measure of human in keeping the pelvis and the contralateral leg active extension case, flexion range of hip joint decided by the gluteus maximus muscle and iliotibial beam combined with muscle group flexibility. So do the iliopsoas muscle and anterior pelvic muscle group flexibility of hip extension amplitude. Therefore, it is related to 50 meters sprints and play an important role of the swing leg fast, powerful, greatly before the pendulum and swinging leg approximate positive under pressure, whipping pawing movement to the body basic movement pattern requirements, and with the sit and reach test main link hip flexibility action pattern corresponds directly; standing long jump is the development of lower limb explosive force and spring force of sports that require leg and hip muscles coordinated push hard and fast. Coordinating the standing long jump test performance improvement depends on the hip and knee and ankle joints and three eruption abilities. A hurdle step action test challenges is hip, knee and ankle of bilateral flexibility and stability, and maintain stability and control ability of the pelvis and the body core part, and standing long jump structure requires approximation. As for the significant correlation is tested only on the left side of the action, this study suggests that the problem may be related to the symmetry of the action pattern. The functional action system considers that an error in a symmetric action pattern may actually contain an asymmetric in an isolated asymmetric motion pattern. And the hurdle step action pattern in a single analysis, found that 25 % of the subjects appear around on both sides of the asymmetry (side 2, side 3); squat and trunk stability pushups is only two symmetric test action of function action screening and both of which are fully coordinated body flexibility and core body parts of the stability of challenge [6]. Squat action on behalf of the human body structure and mechanics of neuromuscular control ability, which is significantly correlated to specialize to measure the 1 min sit ups and 800 m running of girls, shows that girls fully mobilize coordination and flexibility of nervous system in physical fitness test body, speculating that perhaps is to compensate for the lack of strength. Interestingly, most of the girls will not support and hold the trunk stability (1 points), but significant correlation is detected, testing on the stability may be attributed to the reflection of the core parts of the body [7]. The significant correlation of pull ups and trunk stability can be interpreted as body is upper symmetric centrifugal or centripetal movement in closed kinetic chain in mode of action, and maintain the stabilization of the spine in the sagittal plane. 1000 m running is the evaluation of subject endurance quality. For young people, cardiovascular system and respiratory system function should be the main factors affecting the performance, so it has no correlation with functional movement pattern was detected.

Besides, some phenomena worthy deliberation also occurred in the testing process. First of all, in the core stability testing, participants showed that muscular strength in core area was weaker than flexor strength and extensor strength [8]. As ignoring exercise on quadratus lumborum, they can hardly make the correct gestures. Actually, quadratus lumborum is one of the deep multi-function muscles with the highest frequency of use in our daily life. It is not only the best stable muscle for our spine, but a catalyst to low back pain, and has been proven to be closely linked to teenagers' physical quality [9]. What comes next is the "common fault" appeared in the motor function screening testing. For instance, when doing deep knee bends, with hands holding a rod, left shoulder and right shoulder are not on the same level. What's worse, genu valgum while jumping over hurdles, asymmetry in rotation stability testing and failure in trunk stable front support are all predicting problems like asymmetry and motion compensation in teenagers' action patterns [10]. Therefore, studies aim at analyzing muscular characteristics and features of functional movements for teenagers at different ages need to go further.

4 Conclusions and Suggestions

1. The basic functional movement ability of youth is low, and correcting training is needed for them to move well first before improving the physical fitness performance.
2. The low correlation between FMS and PFT indicates that movement quality and physical performance are two independent abilities and could not be replaced by each other.
3. It is suggested that functional movement ability should be tested besides standard physical fitness ability to avoid potential injures and further improve movement and posture of youth.

References

1. National Institute of Child Health and Development: Frequency and intensity of activity of third-grade children in physical education. Arch. Pediatr. Adolesc. Med. **157**, 185–190 (2003)
2. Stanton, R., Reaburn, P.R., Humphries, B.: The effect of short-term Swiss ball training on core stability and running economy. J. Strength Cond. Res. **18**, 522–528 (2004)
3. Tse, M.A., McManus, A.M., Masters, R.S.W.: Development and validation of a core endurance intervention program: implications for performance in college-age rowers. J. Strength Cond. Res. **19**, 547–552 (2005)
4. Scibek, J.S., Guskiewicz, K.M., Prentice, W.E., Mays, S., Davis, J.M.: The effect of core stabilization training on functional performance in swimming. Master's Thesis, University of North Carolina, Chapel Hill (2001)
5. McGill, S.M., Childs, A., Liebenson, C.: Endurance time for low back stabilization exercise: clinical targets for testing and training from a normal database. Arch. Phys. Med. Rehabil. **80**, 941–944 (1999)
6. Nesser, T.W., Huxel, K., Burton, L.: The relationship between core stability and performance in division I football players. J. Strength Cond. Res. **22**, 1750–1754 (2008)
7. Minik, K.L., Kiesel, K., Burton, L.: A reliability study of the functional movement screen (Platform Presentation). In: National strength and conditioning conference, Atlanta, GA (2007)
8. Burton, L., Cook, G.: The functional movement screen: research information. Available at: http://www.functionalmovement.com/SITE/research/FMS_Presentation1207/index.php.htm (2009). Accessed 12 Jan 2009
9. Cook, G.: Weak links: screening an athlete's movement patterns for weak links can boost your rehab and training effects. Train Cond. **12**, 29–37 (2002)
10. Okada, T., Huxel, K.C., Nesser, T.W.: Relationship between core stability, functional movement, and performance. J. Strength Cond. Res. **25**, 252–261 (2011)

Relative Age Effect on Psychological Factors Related to Sports Participation Among Japanese Elementary School Children

Yujiro Kawata, Akari Kamimura, Kazusa Oki, Kai Yamada and Masataka Hirosawa

Abstract Children born soon after the selection period's cut-off date (early-born children) may benefit by up to a full year in physical and psychological development compared with children born just before the cut-off date (late-born children). This phenomenon is called the "relative age effect" (RAE). RAE is defined as the consequence of age differences between individuals within the same cohort, either in school or on sports teams. We examined the RAE on physical activity enjoyment, physical activity competence, attitude toward physical activities, attitude toward physical education, and frequency of participation in physical activities among Japanese elementary school children. Data were collected from 961 Japanese elementary school children (478 male, 483 female). The results showed that early-born children scored higher than late-born children did in the above-mentioned variables. This indicated that the RAE exists for psychological factors related to sports participation among Japanese elementary school children.

Keywords Relative age effect · Physical activity enjoyment · Elementary school · Sports participation · Sports education

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1 Introduction

In a school education system, children are organized into annual age grouping to avoid a large developmental difference by using a specific cut-off date (e.g., April 1 in Japan). In the Japanese educational system, the school year starts on April 1 and ends on March 31. Thus, a child born soon after the selection period's cut-off date (early-born children) may benefit by up to a full academic year in physical and psychological development compared with a child born just before the cut-off date (late born children). This phenomenon is called the "relative age effect" (RAE). RAE is defined as the consequence of age differences between individuals within the same cohort, either in school or on sports teams [1].

The RAE on education has been reported. In most countries, a relative age difference of almost one year is typical in public school systems. The difference of almost one year is related to significant differences in children's cognitive development [2, 3]. Late-born children have more academic problems compared to their early-born classmates [4–7]. Late-born children are more likely to be classified as learning disabled [8, 9], and their academic achievement is significantly lower than that of their older classmates [10]. Late-born children are also more likely to show physically less development even in kindergarten [11–13]. Therefore, late-born children are likely to have an educational disadvantage, even at a young age. Of course, although, the difference in abilities might be decreased and disappear when children grow up, the amount of experience of success may be different between early-born and late-born children. Musch and Grondin [1] pointed out, despite the obvious similarity, there seems to be an important difference between the RAE in sports and education: sports participation is voluntary, while attending school is compulsory.

The age difference is associated with immediate and long-term consequences. About 30 years ago, Grondin et al. [14] firstly reported the RAE in sports, according to the relative age in education. They addressed a possible relationship between relative age and sport participation, in terms of the relationship between relative age and scholastic achievement. They discussed that early-born children in the competition year possess a competitive advantage over their younger peers. Grondin et al. [14] found that the birthdate distribution of ice hockey players in competitive youth hockey leagues and in the main professional ice hockey league in North America, the National Hockey League (NHL) is highly skewed. That is, the number of players born in the first months of the year is greater than that of players born in the last months of the year. Following these reports, a similar phenomenon has been found in other sports, such as baseball, cricket, tennis, swimming, volleyball, handball, and soccer (for a review, see Musch and Grondin [1]). Nakata and Sakamoto [15] also found a similar phenomenon in some sports in Japan. Thus, late-born children may be at a disadvantage in competitive sports.

Although the RAE on sports has been examined in many countries as mentioned above (for a review, see Cobley et al. [16]), the RAE on sports related education, such as physical education, has not been well examined. The possible disadvantages in education applying the relative age is called in question and it may cause disproportionate distributions in the number of professional players. Appropriate support is necessary for children to achieve the maximum benefit from schooling, and a lack of knowledge of the RAE in education is a serious problem. In Japan, Kawata et al. [11, 12] found the existence of RAE on physical development among the 4–5 year-old Japanese kindergarten children and their teachers' evaluations. Specifically, early-born children were more physically developed (e.g., height and weight in physical size, and running and throwing in motor ability) and received higher ratings from teachers in these skills. Kawata et al. [13] found that there was no RAE on the psychological factors related to sports participation among the 4–5 year-old Japanese kindergarten children, that is, children have high enjoyment and confidence in doing physical activity (e.g., running, jumping, and throwing) regardless of their birth month. Among the 4–5-year children, Kamimura et al. [17] indicated that the birth date might influence on the teacher's evaluation mediating their physical fitness and motor abilities.

However, the RAE on psychological factors related to participation in sports is still unclear. Therefore, we focus on the possibility of the RAE on psychological factors related to participation by examining the RAE on physical activity enjoyment, physical activity competence, attitude toward physical activities, attitude toward physical education, and frequency of participation in physical activities among Japanese elementary school children.

2 Method

2.1 Participants

We collected data from 961 Japanese elementary school children (478 male, 483 female) from public elementary schools in Japan.

2.2 Measurements

We carried out a questionnaire to collect information on demographic information (gender, age, birth month, and school grade), physical activity enjoyment, physical activity competence, attitude toward physical activities, attitude toward physical education, and frequency of participating in physical activities. We formed all questionnaire items, considering children's comprehension.

We assessed the physical activity enjoyment using the Physical Activity Enjoyment Scale (PACES [18]). Prior to the survey, we translated the scale into Japanese with the back-translation method. Specifically, the authors translated the items into Japanese, then, an American researcher with a good Japanese proficiency translated the items into English. This procedure was repeated until obtaining the consensus from the all authors. This is a self-report questionnaire using a 5-point Likert scale of agreement. This has a one-factor structure and 16 items. Participants were asked to indicate whether they "strongly agree," "slightly agree," "neither," "slightly disagree," or "strongly disagree" with each statement. The score was calculated by the summation of 16 scored items, with a possible range of 16–80, and from no enjoyment to extremely high enjoyment.

To assesse the physical activity competence, we used the Physical Activity Competence Scale [19]. This is a self-report questionnaire using a 5-point Likert scale of agreement. This has a three-factor structure and 12 items. Participants were asked to indicate whether they "strongly agree," "slightly agree," "neither," "slightly disagree," or "strongly disagree" with each statement. The score was calculated by the summation of 12 scored items, with a possible range of 12–60, and from no competence to extremely high competence.

We assessed the attitude toward physical activities using the question "how much do you like physical activity?" Participants were asked to indicate whether they "strongly agree," "slightly agree," "neither," "slightly disagree," or "strongly disagree." The score was calculated by the summation of one scored item, with a possible range of 1–5, from dislike to an extremely high like.

In order to assess the attitude toward physical education, we used the question "how much do you like physical education?" Participants were asked to indicate whether they "strongly agree," "slightly agree," "neither," "slightly disagree," or "strongly disagree." The score was calculated by the summation of one scored item, with a possible range of 1–5, and from dislike to an extremely high like.

We assessed frequency of participation in physical activities using the question "how much do you do physical activity except for physical education a week?" Participants were asked to indicate whether they do "0," "1–2," "3–4," "5–6," or "Every day." The score was calculated by the summation of one scored item, with a possible range of 1–5, and from dislike to an extremely high like.

2.3 Ethical Consideration

This study was approved by the Research Ethics Committee at the School of Health and Sports Science, Juntendo University. Prior to the study, we obtained permission from the principals of the schools principals and the board of education. Informed consent was obtained from the parents of the participants. Each participant was made aware of his or her right to decline cooperation at any time, even after consenting to participate, without repercussions.

2.4 Statistical Analysis

We divided participants into the following four groups according to the academic calendar quarters based on their birth month: Group A (April 2nd through June), Group B (July through September), Group C (October through December), and Group D (January through April 1), which were aligned with the Japanese school year that runs from April 1 to March 31. Children born on April 1 were placed in Group D because that is the cut-off date for grade placement according to Japanese education law. Group A and B are considered early-bone children, and those in Groups C and D are late-born children. A one-way analysis of variance (ANOVA) was conducted to assess the differences in all variables among the four groups. We calculated the η^2 as an effect size for the each analysis. The effect size is regarded as a statistical measure of the strength of a phenomenon. Thus, we used the effect size to compare the strength of the RAE in this study. The criteria of the effect size of η^2 in the one-way ANOVA analysis are regarded as follows: small effect ($\eta^2 = 0.01$), medium effect ($\eta^2 = 0.06$), and large effect ($\eta^2 = 0.14$) [20]. The statistical significance was set at $p < 0.05$.

3 Results and Discussion

3.1 Demographic Information of Participants

The numbers and percentages of the participants by year grade and gender were presented in Table 1. The number and percentages of the participants were well balanced between each school grade. There was no difference in percentages of each category.

The numbers and percentages of the participants by birth date and gender were also presented in Table 2. The number and percentages of participants were well balanced between the four groups. There was no difference in the percentages of each category.

3.2 RAE on Physical Activity Enjoyment

For boys (Table 3), in the 1st year grade, Group B and C scored significantly higher than Group D. Group A scored significantly higher than Group C in the 2nd and 3rd year grades. For girls (Table 4), Group B and C scored significantly higher than Group D in the 1st year grade. Group B scored significantly higher than Group C in the 2nd year grade. Group A scored significantly higher than Group C and D in 6th year grade. This indicates that early-born children scored higher than late-born children did in some grades: therefore, the RAE exists for physical activity enjoyment.

Table 1 The number of participants by school grade and gender

		Gender		Total
		Male	Female	
1st year grade	N	70	60	130
	%	54	46	100
2nd year grade	N	70	60	149
	%	51	49	100
3rd year grade	N	70	60	165
	%	61	39	100
4th year grade	N	70	60	177
	%	48	52	100
5th year grade	N	70	60	180
	%	47	53	100
6th year grade	N	70	60	160
	%	39	61	100
Total	N	478	483	961
	%	50	50	100

Table 2 The number of participants by groups based on birth date

		Gender		Total
		Male	Female	
Group A (April–June)	N	122	115	237
	%	25.5	23.8	24.7
Group B (July–September)	N	138	97	235
	%	28.9	20.1	24.5
Group C (October–December)	N	111	139	250
	%	23.2	28.8	26.0
Group D (April–June)	N	107	132	239
	%	22.4	27.3	24.9
Total	N	478	483	961
	%	100	100	100

3.3 RAE on Physical Competence

For boys (Table 5), in the 2nd year grade, Group A and B scored significantly higher than Group C. For girls (Table 6), Group B scored significantly higher than Group D in the 2nd year grade. Group B and C scored significantly higher than Group D in the 3rd year grade. Group A scored significantly higher than Group B and D in 6th year grade. This indicates that early-born children scored higher than late-born children did in some grades: therefore the RAE exists for physical competence.

Table 3 The RAE on physical activity enjoyment (boys)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.3	0.6	4.6	0.5	4.1	0.6	4.0	0.8	3.9	*	B > C & D	0.15
2nd year grade	4.6	0.3	4.4	0.4	4.0	0.7	4.4	0.4	4.4	**	A > C	0.16
3rd year grade	4.6	0.6	4.4	0.7	4.0	1.2	4.0	1.1	3.1	*	A > C	0.09
4th year grade	4.5	0.7	4.5	0.4	4.5	0.4	4.6	0.3	2.6	–	–	0.08
5th year grade	4.4	0.5	4.3	0.7	4.1	0.8	4.3	0.7	0.9	–	–	0.03
6th year grade	4.3	0.5	4.4	0.5	4.4	0.5	4.3	0.3	0.1	–	–	0.01

$^{*}p < 0.05$, $^{**}p < 0.01$

Table 4 The RAE on physical activity enjoyment (girls)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.5	0.5	4.8	0.3	4.7	0.5	4.0	0.7	3.8	*	B & C > D	0.17
2nd year grade	4.4	0.4	4.7	0.5	4.0	0.9	4.0	0.5	4.8	**	B > C	0.17
3rd year grade	3.9	0.8	4.5	0.4	4.4	0.4	4.2	0.6	1.9	–	–	0.09
4th year grade	4.0	0.7	4.1	0.6	4.2	1.1	4.0	0.9	0.6	–	–	0.02
5th year grade	4.0	0.9	3.9	0.7	4.0	1.0	4.1	0.9	0.1	–	–	0.00
6th year grade	4.2	0.6	3.8	0.6	3.6	1.0	3.5	0.8	3.3	*	A > C & D	0.10

$^{*}p < 0.05$, $^{**}p < 0.01$

3.4 RAE on Attitude Toward Physical Activities

For boys (Table 7), in the 2nd year grade, Group A scored significantly higher than Group C. Group A scored significantly higher than Group D in the 3rd year grades. For girls (Table 8), Group A scored significantly higher than Group C and D in the 6th year grade. This indicates that early-born children scored higher than late-born children did in some grades: therefore, the RAE exists for attitude toward physical activities.

Table 5 The RAE on physical competence (boys)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	51.4	8.4	51.1	9.2	48.3	7.0	44.9	10.3	1.7	–	–	0.07
2nd year grade	44.4	8.2	49.5	4.3	49.2	10.0	47.8	8.6	1.7	**	A & B > C	0.07
3rd year grade	47.8	9.8	50.2	10.6	38.8	14.9	41.5	1.1	4.8	–	–	0.13
4th year grade	48.6	8.2	51.1	4.9	49.6	7.2	48.3	0.3	0.7	–	–	0.03
5th year grade	47.3	8.7	44.9	10.9	43.4	10.5	47.0	0.7	0.7	–	–	0.03
6th year grade	49.2	7.3	47.8	10.0	42.2	10.8	49.0	0.3	1.6	–	–	0.07

** $p < 0.01$

Table 6 The RAE on physical competence (girls)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	51.6	5.0	51.9	7.9	54.6	4.7	51.6	11.5	1.1	–	–	0.06
2nd year grade	50.0	4.9	52.7	4.5	47.2	9.9	44.8	10.2	3.2	*	B > D	0.12
3rd year grade	43.5	6.4	48.7	5.4	47.4	3.3	39.1	9.7	5.4	**	B & C > D	0.21
4th year grade	42.2	11.9	42.5	10.2	44.8	12.3	41.5	12.7	0.3	–	–	0.01
5th year grade	43.4	10.4	43.3	9.6	42.5	11.4	45.4	7.4	0.5	–	–	0.01
6th year grade	43.7	6.2	37.3	7.6	38.4	9.3	37.4	5.7	3.9	*	A > B & D	0.11

* $p < 0.05$, ** $p < 0.01$

Table 7 The RAE on attitude toward physical activities (boys)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.6	0.7	4.7	0.7	4.1	1.0	4.7	0.5	2.4	–	–	0.10
2nd year grade	4.9	0.4	4.7	0.5	4.4	0.5	4.7	0.3	4.1	*	A > C	0.15
3rd year grade	4.5	0.8	4.5	0.8	4.2	0.9	3.9	1.1	2.6	*	A > D	0.07
4th year grade	4.5	0.8	4.8	0.4	4.7	0.7	4.8	0.4	1.6	–	–	0.06
5th year grade	4.7	0.8	4.3	1.0	4.3	0.9	4.3	0.5	1.2	–	–	0.04
6th year grade	4.4	1.4	4.5	0.7	4.4	0.5	3.7	1.6	2.1	–	–	0.10

*$p < 0.05$

Table 8 The RAE on attitude toward physical activities (girls)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.8	1.4	5.0	0.0	5.0	0.0	5.0	0.0	2.4	–	–	0.10
2nd year grade	4.7	0.5	4.8	0.6	4.4	1.1	4.3	0.7	1.7	–	–	0.07
3rd year grade	4.6	1.1	4.6	0.5	4.6	0.5	4.4	0.6	1.6	–	–	0.06
4th year grade	4.2	0.8	4.4	0.8	4.3	1.1	4.3	0.7	0.3	–	–	0.01
5th year grade	3.9	1.3	4.3	0.9	4.1	1.1	4.3	1.1	0.6	–	–	0.02
6th year grade	4.4	0.6	3.8	0.7	3.4	1.2	3.5	1.1	5.8	**	A > C & D	0.16

**$p < 0.01$

3.5 RAE on Attitude Toward Physical Education

For boys (Table 9), in the 6th year grade, Group A, B, and C scored significantly higher than Group D. For girls (Table 10), Group A scored significantly higher than Group C and D in the 6th year grade. This indicates that early-born children scored higher than late-born children did in some grades: therefore, the RAE exists for attitude toward physical education.

Table 9 The RAE on attitude toward physical education (boys)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.4	1.0	4.7	0.7	4.8	0.4	4.2	1.4	1.9	–	–	0.08
2nd year grade	4.7	0.5	4.6	0.8	4.6	0.5	4.8	0.4	0.6	–	–	0.02
3rd year grade	4.7	0.7	4.7	0.7	4.2	0.9	4.4	1.2	2.1	–	–	0.06
4th year grade	4.5	0.8	4.9	0.4	4.7	0.7	4.9	0.3	2.3	–	–	0.08
5th year grade	4.3	0.6	4.2	1.3	4.4	0.9	5.0	0.0	1.6	–	–	0.06
6th year grade	4.5	0.5	4.5	0.5	4.5	0.5	3.3	1.5	7.4	**	A, B, & C > D	0.28

$^{**}p < 0.01$

Table 10 The RAE on attitude toward physical education (girls)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	4.7	0.7	5.0	0.0	4.8	0.6	5.0	0.0	0.8	–	–	0.04
2nd year grade	4.7	0.5	4.9	0.3	4.3	1.0	4.5	0.5	2.7	–	–	0.11
3rd year grade	4.6	0.9	4.5	0.0	4.6	0.5	4.7	0.6	0.8	–	–	0.04
4th year grade	4.4	0.6	4.5	0.6	4.6	0.8	4.3	0.9	1.2	–	–	0.04
5th year grade	4.1	1.0	4.6	1.0	4.2	0.8	4.4	1.1	0.6	–	–	0.02
6th year grade	4.5	0.5	4.2	0.8	3.6	1.2	3.6	1.3	3.4	*	A > C & D	0.10

$^{*}p < 0.05$

3.6 RAE on Frequency of Participation in Physical Activity

For boys (Table 11), in the 1st year grade, Group A, B, and D scored significantly higher than Group C. Group C scored significantly higher than Group D in the 4th year grades. Group A scored significantly higher than Group C in the 5th year grades. In girls, Group A scored significantly higher than Group C in the 3rd year grade. This indicates that early-born children scored significantly higher than late-born children did in some grades: therefore, the RAE exists for frequency of participation in physical activities (Table 12).

Table 11 The RAE on frequency of participation in physical activities (boys)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	3.9	1.2	3.9	1.6	2.3	1.2	4.2	1.4	7.3	**	A, B, & D > C	0.25
2nd year grade	2.9	1.5	3.1	1.5	3.1	0.7	2.5	1.0	0.8	–	–	0.03
3rd year grade	3.1	1.5	3.3	1.3	2.9	1.4	3.6	1.5	1.1	–	–	0.03
4th year grade	3.0	1.3	3.5	1.5	4.2	1.3	3.0	1.0	4.7	**	C > D	0.15
5th year grade	3.8	1.2	2.9	1.2	2.6	1.3	2.7	1.8	4.3	**	A > C	0.14
6th year grade	3.5	1.1	3.4	1.1	2.7	0.7	3.1	1.0	1.8	–	–	0.09

** $p < 0.01$

Table 12 The RAE on frequency of participation in physical activities (girls)

	Group A		Group B		Group C		Group D		Main effect		Multiple comparison	Effect size
	M	SD	M	SD	M	SD	M	SD				
1st year grade	3.4	1.5	3.6	1.6	3.1	1.5	3.8	1.6	0.6	–	–	0.03
2nd year grade	3.0	1.9	2.1	1.3	2.6	1.4	2.5	0.8	1.0	–	–	0.04
3rd year grade	2.8	1.3	2.8	0.8	1.8	0.4	2.3	0.8	3.2	*	A > C	0.14
4th year grade	2.2	1.1	2.6	1.1	3.1	1.4	2.7	0.9	1.9	–	–	0.07
5th year grade	2.5	0.8	2.6	0.8	2.4	1.0	2.7	0.9	0.6	–	–	0.02
6th year grade	2.5	1.4	1.8	1.0	2.1	0.6	2.4	0.6	2.3	–	–	0.07

* $p < 0.05$

The aim of this study was to examine the RAE on physical activity enjoyment, physical activity competence, attitude toward physical activities, attitude toward physical education, and frequency of participation in physical activities among Japanese elementary school children. The result showed that RAE was found in all variables in both boys and girls. This evidenced that the RAE exists in the psychological factors related to participation in physical activities among elementary school children.

The effect size of the RAE differs by gender and school year grades. Specifically, the RAE on physical activity enjoyment was found in the 1st and 2nd year grades, indicating the RAE on physical activity enjoyment is likely to appear in early elementary grades. While, the RAE on attitude toward physical education was found in the 6th year grade, thus, indicating the RAE on attitude toward physical education is likely to appear relatively late in the elementary grades.

Although, the RAE on psychological factors related to sports participation among 4–6 year-old Japanese children was not found in our previous study [13], among 7–12 year-old children, the RAE on psychological factors was found in this study. This indicates that the RAE on psychological aspects may appear at elementary-age.

From these results, teachers and coaches should consider the RAE when teaching physical activity to children. Early-born children are profiting from an initial relative age advantage and are likely to be perceived as the most talented in their age group because RAE is not understood, as Musch and Grondin [1] suggested. Accordingly, increased teacher understanding of the RAE may lead to the provision of age-appropriate support for children's healthy development and fair achievement across all grade levels.

4 Conclusion

The RAE exists in the psychological factors related to sports participation among Japanese elementary school children. However, the effect size differed by sex and grade. We thus propose a need to consider the existence of this phenomenon to improve school education programs. Teachers and sports coaches could benefit from an awareness of the RAE when teaching sports.

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References

1. Musch, J., Grondin, S.: Unequal competition as an impediment to personal development: a review of the relative age effect in sport. Dev. Rev. **21**(2), 147–167 (2001)
2. Bisanz, J., Morrison, F.J., Dunn, M.: Effects of age and schooling on the acquisition of elementary quantitative skills. Dev. Psychol. **31**(2), 221 (1995)
3. Morrison, F.J., Smith, L., Dow-Ehrensberger, M.: Education and cognitive development: a natural experiment. Dev. Psychol. **31**(5), 789 (1995)
4. Bell, J.F., Daniel, S.: Are summer-born children disadvantaged? The birthdate effect in education. Oxford Rev. of Educ. **16**, 67–80 (1990)
5. Dickinson, D.J., Larson, J.D.: Effects of chronological age in months on school achievement. J. Edu. Res. **56**, 492–493 (1963)
6. Gilly, M.: Mois de naissance et réussite scolaire. Enfance **18**(4), 491–503 (1965)
7. Hauck, A.L., Finch, A.: The effect of relative age on achievement in middle school. Psychol. Schools **30**(1), 74–79 (1993)

8. Diamond, G.H.: The birthdate effect—a maturational effect? J. Learn Disabil. **16**(3), 161–164 (1983)
9. Maddux, C.D.: First-grade entry age in a sample of children labeled learning disabled. Learn. Disabil. Q. **3**(2), 79–83 (1980)
10. Davis, B.G.: Does age of entrance affect school achievement? Elem. Sch. J. **80**(3), 133–143 (1980)
11. Kawata, Y., Iizima, M., Izutsu, S., Yamada, K., Kamimura, A., Hirosawa, M.: The relative age effect on physical fitness, motor ability, physical competence and evaluation from kindergarten teachers among Japanese young children. In: Proceedings of the 8th Asian Preschool Physical Education Conference and PE Workshop for Kindergarten Teachers, China, CD-ROM (5 pages), Beijing (2012)
12. Kawata, Y., Kamimura, A., Izutsu, S., Yamada, K., Iijima, M., Hirosawa, M.: Does the relative age effect exist in physical size, motor ability, awareness of physical activity, and kindergarten teachers' evaluation of young Japanese children? In: Abstract of the ISSP 13th World Congress of Sports Psychology, p. 247. (2013)
13. Kawata, Y., Kamimura, A., Izutsu, S., Yamada, K., Iizima, M., Mizuno, N., Hirosawa, M.: Relative age effect in physical and psychological development in young Japanese children and associated problems for kindergarten teachers. In: Ahram, T., Karwowski, W., Marek, T. (eds.) Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics, AHFE 2014, pp. 414–419. AHFE Conference, Poland (2014)
14. Grondin, S., Deshaies, P., Nault, L.: Trimestres de naissance et participation au hockey et au volleyball. La Revue Québecoise de l'Activité Physique **2**(3), 97–103 (1984)
15. Nakata, H., Sakamoto, K.: Relative age effect in Japanese male athletes. Percept. Motor Skill **113**(2), 570–574 (2011)
16. Cobley, S., Baker, J., Wattie, N., McKenna, J.: Annual age-grouping and athlete development. Sport Med. **39**(3), 235–256 (2009)
17. Kamimura, A., Kawata, Y., Hirosawa, M.: The relationship between birth month, physical size, motor ability and physical activity evaluated by kindergarten teachers among Japanese young children. International Academy of Sportology (in press)
18. Moore, J.B., Yin, Z., Hanes, J., Duda, J., Gutin, B., Barbeau, P.: Measuring enjoyment of physical activity in children: validation of the physical activity enjoyment scale. J. Appl. Sport. Psychol. **21**(S1), S116–S129 (2009)
19. Okazawa, Y., Kitani, H., Kitani, M.: Perceived physical competence scale for children and its developmental tendency and gender difference. Bull. Nara Univ. **50**(1), 91–95 (In Japanese) (2001)
20. Cohen, J.: Statistical power analysis for the behavioral science. Academic Press, New York (1969)

User Interface Evaluation of a Ski Injuries Management System

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Abstract Although many technological devices and solutions to enhance the skiing experience are now available for skiers, skiing sometimes could turn to be potentially dangerous. The speed of movement, environment unpredictability, and variable weather conditions, among others, can contribute to some of the most common skiing injuries that skiers incur. In this paper, we conduct an interface prototype evaluation of a ski injury registration system architecture that is already developed. This system will improve the communication from the ski resort to the medical center, in case an injury has occurred. The results of the interface evaluation indicate that the ski patrollers showed very positive attitude and experience with this prototype. Furthermore, the post-task and SUS (System Usability Scale) question results showed very high score for all participants, indicating that locating the body parts and the right injury was very easy using the interface.

Keywords Ski patroller · User interface · Usability analysis · Mobile app

1 Introduction

Skiing is very popular recreational activity that brings people together to enjoy and carry out physical exercises. This popularity is also related to injuries, which sometimes may be even fatal for skiers. Skiers experience variable terrain and

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weather conditions, high speeds, and obstacles including other people and structures (e.g., trees, fences, poles), all increasing the chance of a severe injury [1].

Today, the use of mobile devices and applications (*mHealth*) in healthcare have become a global reality. *mHealth* and cloud computing can offer the potential to extend the scope of health services, efficiently deliver and access the care and make the healthcare better and cheaper. Inspired by the need of integrating *mHealth* apps in managing skiing injuries to provide higher healthcare service quality and faster availability of data, we have developed and presented a system architecture for ski injury registration [2]. The workflow scenario of the system is presented in Fig. 1.

As shown in Fig. 1, using the SkiPatrol App the ski patroller is able to provide patient information to doctors at health centers in a timely manner. Consequently, the system greatly simplifies the workflow between ski patrollers and medical staff as well as it helps improve the delivery of healthcare services. An example for such improvement is whether the injured person can be treated at a local center or should be directly transferred to a fully equipped hospital. Another benefit would be the proper scheduling of medical personnel in expectation of a certain number of injuries due to certain indicators e.g., month of season, precipitation level, temperature.

The described system has only been tested preliminarily, and the main goal of this paper is to conduct an interface evaluation analysis of the ski injury registration system for further development. We present the screenshots of the app developed and describe the specifications for the ski patrol interface. The ski patrol app requirements were generated by observing the working conditions of ski patrols in the mountains of Trysil, Norway. Our aim is to find out whether the existing app

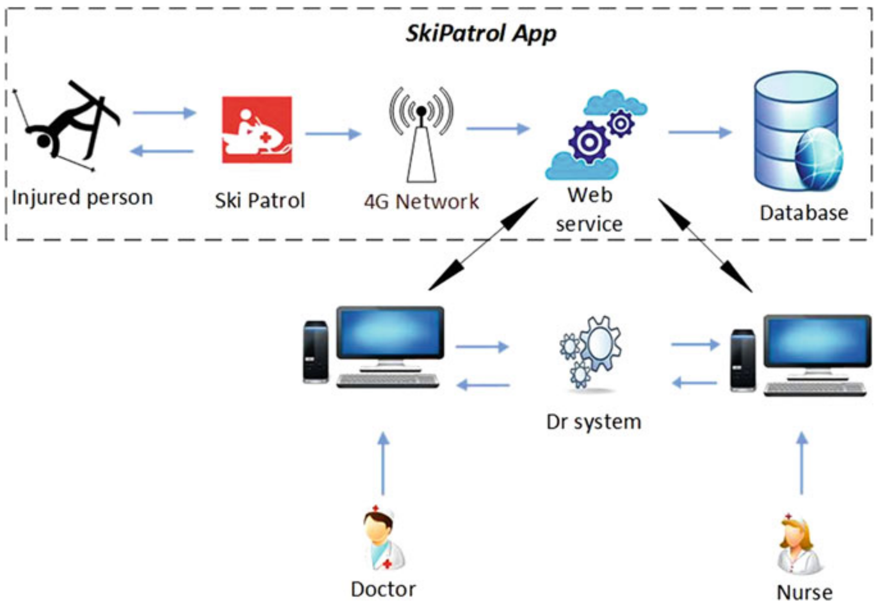

Fig. 1 Workflow scenario of the ski injury registration system

interface is satisfactory for the users and whether there is need for any improvements.

The rest of the paper is structured as follow: in Sect. 2, we present the related work in the field. Section 3 provides a description of the interface design, whereas Sect. 4 presents the experimental setting. In Sect. 5, we present the findings and discussions. Lastly, Sect. 6 concludes this paper.

2 Related Work

In recent years the research community has presented many alternatives to support various aspects of developing mobile healthcare system [3–9]. Pflegning and Schmidt in a seminal paper describe the ways of enhancing the ski experience by applying ubiquitous connectivity [10].

Fedosov et al. [11] discuss empirical findings related to challenges and opportunities to using personal and situated devices on ski lifts. Authors also propose possible applications that could support user needs and enhance the overall skiing experience. Fedosov and Langheinrich [12] provide some design ideas for mobile and wearable devices to enhance group-sharing behavior in a skiing community. This work reports result of an exploratory research study conducted with seven experienced skiers and discovered that sharing information is a fundamental pillar that contributes to a positive skiing experience. Another research work, proposed by [13] is performed in ski injury analysis and a decision guidance support system is under development for early warning for ski injuries. Depending on the movement of skiers, the system is able to calculate average speed of skier, average weight of slopes, etc.

As far as the technological devices are considered, devices as Penetrometer [14] warns the participants for an avalanche or accident, and RECCO system [15] can also help enhance skiing safety. The RECCO detector, which is a small reflector included in ski clothes, such as coats, echoes the signal of radar carried by ski patrol or other rescue teams when an avalanche has buried someone.

Nevertheless, very scarce is the research addressing the challenges and benefits of existing systems for digital management of ski injuries using mobile apps [16, 17]. In his study, Jeppesen in [17] identified a need for better management of ski injury related data when doing research on ski injuries at the local ski resort. The result of that research showed an under reporting of potential severe injuries by approximately 50 %, due to the limitations of using a paper based system.

The main challenge of such a system lies in delivering of treatment with reasonable response time, free of errors, and with proper use of human resources. In order to achieve such goal, we have designed, developed and introduced a complete system architecture that addresses these challenges [2]. The advantage of such a system would be availability of data concerning each injury, such as injured person related information and suspected injury type to medical personnel in advance.

The system also addresses the instant transfer of person to a convenient health institution immediately when the incident occurs. In addition to addressing the stated challenges, the system also provides statistical data (e.g., the number of injured people per month of a season), which could be useful in predicting skiing injuries [18, 19], or in the planning of health and emergency services locally or nationally.

3 User Interface Design and Interactions

The user interface design and interactions were conceptualized for increased usability, while maintaining its simplistic appeal. The interactions implemented in the interface involve only tapping on objects visible on the screen. Other interactions, such as, swipe, pinch or other complicated actions involving two or more fingers, purposefully have not been considered in our design to eliminate difficulties likely to occur when interacting in cold weather conditions, e.g., while wearing gloves.

After the initial login page requiring user's credentials, the interface displays a full body image as shown in Fig. 2a. To access details of a particular body part, the

Fig. 2 User interface. **a** Full body image. **b** Left arm image

user is required to tap on a specific part (head, neck, shoulder, chest, stomach and extremities). For instance, when a user single taps on the left arm of Fig. 2a, the zoomed-in image of left arm with details is shown as in Fig. 2b. Alternatively, tapping on the left leg, shows more details such as knee, heel, etc., as depicted in Fig. 3a. The user then could tap on the labels (e.g., knee, heel, etc.) in the zoomed-in image of the left leg to indicate an injury of that body part. Once the appropriate label is tapped upon, the user is automatically forwarded to the next screen where she/he could record person's injury information, as shown in Fig. 3b. Here, the user selects the type of injury, its severity, and confirm personal information for the injured person, which is already provided by the interface prototype. The same process is followed for the other body parts as well. This step completes the data gathering and the user has the option to submit the data or to return to the latest screen to make a change.

In this version of the prototype, we did not explore the part when the user enters patient's personal information, thus data input is simulated by the prototype. Considering that typing is difficult in cold weather conditions, other modalities should be explored. We discuss this further in Sect. 5.

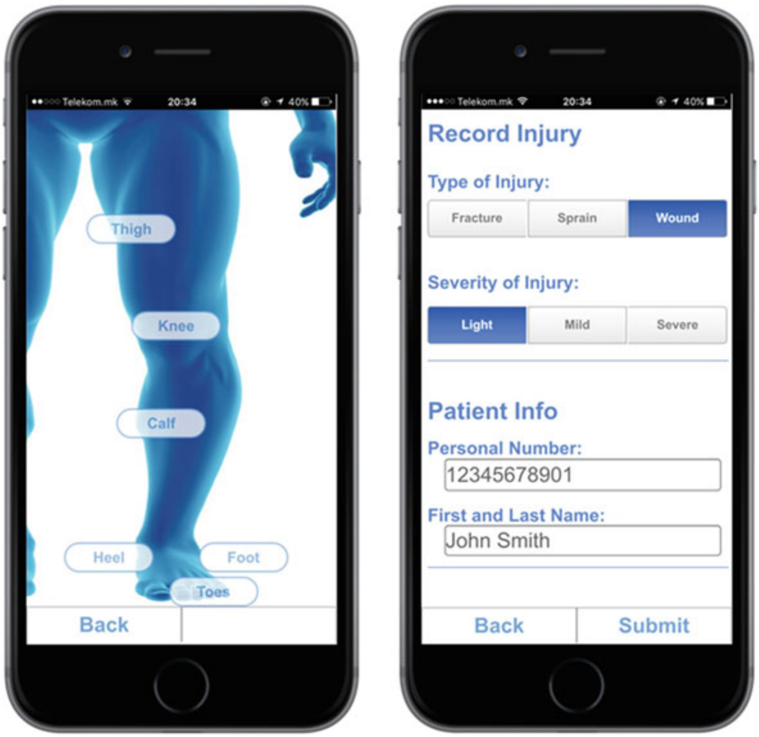

Fig. 3 User interface. **a** Left leg image. **b** Information on injured person

4 Experimental Design

4.1 Overview

In order to evaluate the initial proposed design of the interface prototype, we conducted a preliminary evaluation with people who do ski patrolling and are familiar with the context in which this app will be typically used. The experimental design required participants to complete two tasks, three questions after each task, and 10 standardized questions from the system usability scale (SUS) questionnaire. Participants were also encouraged to provide comments. We used an iPhone 6+ as a device to test the prototype.

4.2 Participants

Three professional ski-patrolling participants used our prototype in two different ski resorts in Macedonia. Two participants were between 30 and 40 years old, while one of them was in his late twenties. Two participants had two-to-four years of experience in ski patrolling, while one had five-to-ten years. They all had five-to-ten years of experience of using smartphones.

4.3 Procedure and Data Collection

The evaluation of the prototype was conducted in two steps. First, participants were asked to perform two tasks and answer three questions after each task. We judged that providing two tasks was optimal due to the simplicity of the interface. The following were the tasks:

Task 1 While ski patrolling, you have just found an injured person, who has injured his left elbow. More specifically, he has suffered a mild fracture. Report this using the app

Task 2 After reporting the first injury, you actually see that the person has also a light wound on his right knee. Please, report it using the app.

After the participants completed each of the task, we asked them three questions to judge the immediate user experience with the tasks. On a 5-point Likert scale ranging from Strongly Disagree to Strongly Agree, participants were asked the following questions:

- Q1: Was it easy to locate the body part, in this case, left elbow? [*right knee, task 2*]
- Q2: Was it easy to locate the right injury, in this case, mild fracture? [*light wound, task 2*]
- Q3: Overall, was it easy to complete this task?

Table 1 SUS questions and scores for each participant

SUS questions	P1	P2	P3	Avg
1. I think that I would like to use this app frequently	4	5	5	4.67
2. I found the app unnecessarily complex	1	2	2	1.67
3. I thought the app was easy to use	5	5	5	5.00
4. I think that I would need the support of a technical person to be able to use this app	1	1	1	1.00
5. I found the various functions in this app were well integrated	3	4	4	3.67
6. I thought there was too much inconsistency in this app	1	1	1	1.00
7. I would imagine that most people would learn to use this app very quickly	5	5	5	5.00
8. I found the app very cumbersome to use	1	1	1	1.00
9. I felt very confident using the app	4	5	5	4.67
10. I needed to learn a lot of things before I could get going with this app	1	1	2	1.33
Percentile SUS score	90	95	92.5	

After the completion of the tasks and related post-task questions, as a following step, we administered a SUS questionnaire in order to assess the user experience with the current version of the prototype's interface. The goal was to capture participants' overall experience concerning their interaction with the interface for the ski patrol app. The standard version of the SUS questionnaire was used as shown in Table 1.

5 Findings and Discussion

The results of the preliminary user evaluation of our ski injury management prototype interface indicate very positive attitude and experience from our participants. The post-task question results showed very high score for all participants, indicating that locating the body parts and the right injury was very easy using the interface.

The SUS questionnaire results were analyzed using the methodology described in [20]. The results show very high percentiles (over 90) for all three participants as shown in Fig. 4. This is an indication that users highly rated the interface and are likely to recommend it to others. Further details for each question and participant are shown in Table 1.

The participant with lowest score (P1: 90) provided comments explaining in his view the weakest points of the prototype. A very accurate observation from him was that the prototype in its current version provides only frontal body parts and extremities, but not the back. The participant commented that the interface should be more comprehensive and provide a way to report injuries of the back, such as, the spinal cord and lower back parts, including hips and buttocks. Additionally, this

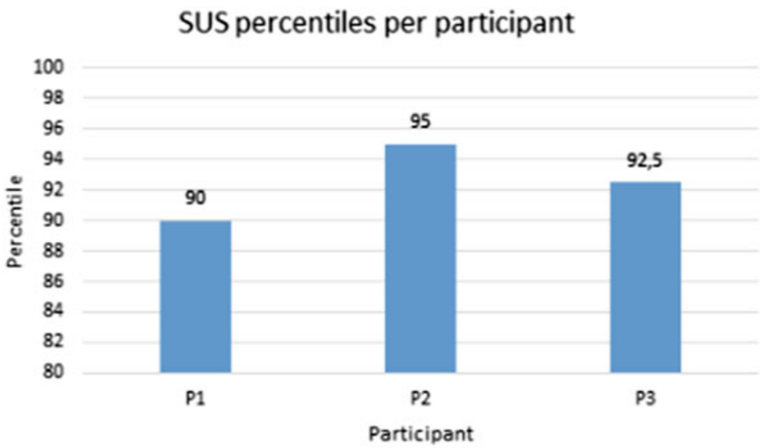

Fig. 4 SUS percentiles per participant

participant explained that the internet access is limited in some parts of the ski trails, thus the application should consider this and provide offline mode of operation. Other participants gave generally positive comments with one participant expressing that the image of the body shown on the prototype should show more natural skin colors.

One important aspect that we did not explore using this version of the interface prototype is inputting patient's personal data. Given the device's small screen and the harsh weather conditions this app is typically used, which imposes use of gloves, the traditional data input using keyboard and letter typing is not ideal. For this reason, the prototype excludes inputting textual information using keyboard and letter typing. At this stage, our goal was to only evaluate other aspects of the interface. We consider that other non-traditional data input modalities, such as speech interaction, could be more appropriate for an app of this kind, however, that remains to be explored and tested in our future versions.

6 Conclusion and Future Work

Despite the fact that this evaluation only included three participants, the positive findings indicate that the prototype has a very good potential and its interface provides the desired interactions potentially required in a skiing environment by ski patrollers for reporting an injury. In addition, this preliminary evaluation provided us valuable information about the future steps needed to be taken in order to improve this application, and whether the app requires in advance learning of knowledge.

Our evaluation of the prototype consisted of two stages: providing the patrollers with two tasks to achieve, and asking each patroller three questions to answer right after each task. Afterwards, in order to assess the user experience of the current version of the prototype, we provided a SUS questionnaire to the patrollers consisting of questions related to the ease of use, convenience and confidence in using the app and the interface.

The SUS score obtained for each participant was equal to or above 90, which indicates ease of use, no need of technical support, convenience and confidence in use, well integration of functionalities and no need for any type of knowledge learning in advance to use.

In the future, we plan to investigate non-traditional modalities when providing data input using the SkiPatrol app, considering the context of use in cold weather conditions. Based on comments received during this evaluation, the interface will also include back body parts. Additionally, the app should be made to run in offline mode to consider places when cellular network is lacking.

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References

1. Creyer, E.H., Ross, W., Evers, D.: Risky recreation: an exploration of factors influencing the likelihood of participation and the effects of experience. Leisure Stud. **22**(3), 239–253 (2003)
2. Yayilgan, Y.S., Du, Y., Dalipi, F., Jeppesen, J.: A novel system architecture for efficient management of skiing injuries. In: 9th IEEE International Conference on Interactive Mobile Communication, Technologies and Learning. Thessaloniki, Greece (2015)
3. Boukerche, A., Ren, Y.: A secure mobile healthcare system using trust-based multicast scheme. IEEE JSAC **27**, 387–399 (2009)
4. Banerjee, A., Gupta, S.K.S.: Analysis of Smart Mobile Applications for Healthcare under Dynamic Context Changes. IEEE Trans. Mob. Comput. **14**(5), (2015)
5. Sebestyen, G., Hangan, A., Oniga, S., Gal, Z.: eHealth Solutions in the Context of Internet of Things. In: IEEE International Conference on Automation, Quality and Testing, Robotics. Cluj-Napoca, Romania (2014)
6. Andry, L.W.F., Nicholson, D.: A mobile application accessing patients health record through a REST API. In: The 4th International Conference on Health Informatics, pp. 27–32 (2011)
7. Griffin, L., Foley, C., de Leastar, E.: A hybrid architectural style for complex healthcare scenarios. In: IEEE International Conference on Communications Workshops, pp. 1–6. Dresden (2009)
8. Li, H.B., Kohno, R.: Body area network and its standardization at IEEE 802.15.BAN. In: Advances in Mobile and Wireless Communications, series: Lect. Notes Electr. Eng. **16**(4), pp. 223–238. Springer, Berlin Heidelberg (2008)
9. Ng, W.S., Teo, J.C.M., Ang, W.T., Viswanathan, S., Tham, C.K.: Experiences on developing SOA based mobile healthcare services. In: IEEE Asia Pacific Services Computing Conference, pp. 498–501. Singapore (2009)
10. Pfleging, B., Schmidt, A., Michahelles, F.: Ubiqoitous Connectivity in the Mountains: Enhancing the Ski Experience. Pervasive Comput. **12**(2), IEEE CS (2013)

11. Fedosov, A., Alt, F., Niforatos, E., Elhart, I.: Supporting interactivity on a ski lift. In: UbiComp/ISWC'15 Adjunct, Osaka, Japan, 7–11 Sept 2015
12. Fedosov, A., Langheinrich, M.: From start to finish: understanding group sharing behavior in a backcountry skiing community, MobileHCI'15. Copenhagen, Denmark, 24–27 Aug 2015
13. Delibaic, B., Obradovic, Z.: Towards a DGSS prototype for early warning for ski injuries. In: IEEE 28th International Conference on Data Engineering Workshops (ICDEW), Arlington, USA (2012)
14. NewScientist: Penetrometer predicts risk of avalanches, Swiss Federal Institute for Snow and Avalanche Research (Internet) (cited 7 March 2016). Available from: https://www.newscientist.com/article/dn3410-penetrometer-predicts-risk-of-avalanches/
15. RECCO®, The RECCO® System (Internet) 2013 (cited 25 Feb 2016). Available from: http://www.recco.com/the-recco-system
16. M52, Ski patrol software, (Internet) (cited 29 Feb 2016). Available from: https://www.medic52.com/
17. Jeppesen, J.C.: Risk of injury in Norwegian alpine resorts—do we know it?. In: The Proceedings of PMU (2012)
18. Dalipi, F., Mendoza, D.M.A., Imran, A.S., Yayilgan, Y.S.: An intelligent model for predicting the occurrence of skiing injuries. In: The 5th IEEE National Symposium on Information Technology: Towards New Smart Worlds—Wireless Systems and Networks. Riyadh, Saudi Arabia, 17–19 Feb 2015
19. Dalipi, F., Yayilgan, Y.S.: The impact of environmental factors to skiing injuries: Bayesian regularization neural network model for predicting skiing injuries. In: The 6th IEEE International Conference on Computing, Communication and Networking Technologies, (ICCCNT2015). Denton, USA, 13–15 July 2015
20. Brooke, J.: SUS—A Quick and Dirty Usability Scale. Digital Equipment Co Ltd., Reading, UK (1996)