Chapter 7
Analysis of Musculoskeletal Disorder (MSD) Risk Factors Among Washing Machine Users in South Region of India

P. Shrisowmya, T. Aravind Krishna, S. Monisha Gowri, and K. Adalarasu

1 Introduction

Washing may be a physical task, which is completed almost everywhere around the world. From the first decades to today, laundry was and still is completed manually. It's seen as physically demanding and time-consuming work. Occasionally, the entire family is involved in managing the laundry. Counting on people's income, washing was and still is usually handed over to launderers or laundresses. Many stories also as paintings underline the intensity of this work. Manual washing may be a physically demanding task in terms of awkward body postures (Balasubramanian et al. 2008; Ejiko et al. 2020), repetitive movements and high energetic workload, due to the physical agitation and wringing to urge the laundry clean. Moreover, the detergents together with high water temperatures also can be hazardous (Huang et al. 2018).

In the recent few decades, the utilization of laundry machines for easy laundry rather than hand-washing has become quite common among several households. It's a blessing for the operating population, elderly (Huang et al. 2018), and maids because it significantly reduces the physical strain and time related to manual laundry. At the time laundry machines were fictional, most of them were supported the principle of a tub. Then on the previous principles of

P. Shrisowmya
Caraway Pharma Pvt Ltd, Bangalore, India

T. A. Krishna
Centre for Business Research in Data Logic and Analysis, Coimbatore, India

S. M. Gowri
Department of Electronics and Communication Engineering, College of Engineering, Anna University, Guindy, Chennai, Tamil Nadu, India

K. Adalarasu (✉)
Department of EIE, SEEE, SASTRA Deemed To Be University, Thanjavur, Tamil Nadu, India
e-mail: adalarasu@eie.sastra.edu

N. K. Rana et al. (eds.), *Technology Enabled Ergonomic Design*, Design Science and Innovation, https://doi.org/10.1007/978-981-16-6982-8_7

a tub, high loaders rotating around vertical axis become widespread. Subsequently, laundry machines were designed as front loaders, rotating around a vertical axis.

Though washing machine designs have evolved over years toward reducing physical effort, there are still a few basic tasks such as loading and unloading clothes, operating controls, and panels, which are strenuous during operation and prone to health issues in the long run. Washing is also an activity, which is very hard to perform for elderly people (Barrett and Kirk 2000). The development of musculoskeletal disorders (MSDs) is the common problem among washing machine users. Ergonomic study and recommendations help to address such issues and ensure the well-being and safety of the users (Balasubramanian et al. 2008). Ergonomic assessment is an essential part of ergonomic assessments and interventions. It helps in targeting improvements toward enhancing quality of life (Baumgartner et al. 1998; Balasubramanian et al. 2014).

Ishihara et al. (2008) studied the postures assumed by washing machine users using three-dimensional motion capture devices. The working postures measured were analyzed using human kinematic models (3D SSPP). The model was used to estimate theoretical values of muscle tension and loads on the lumber vertebrae, knees, and ankles. The study recommends a new washing machine design, which will need only 40% of the muscular force required as compared with conventional washing machines.

Keiko et al. (2015) used Kansei ergonomics (tool for product development) for studying the posture of users while using washing machine. Measurement of working posture showed that slanted drum design was superior compared with the horizontal drum or conventional vertical designs. Ergonomic Function Deployment (EFD) was used to improve the design of the product according to the ECSHE principle (Effective, Comfortable, Safe, Healthy and Efficient) (Fakhriza et al. 2017; Beniuk et al. 2011). The results of this study used the concept of ergonomic products based on product attributes referring to the principle of ENASE (Effective, Safe, Healthy, Comfortable, and Efficient). Rapid Entire Body Assessment (REBA) to evaluate the body postures while using clothes dryer and obtained Motion data using three-dimensional motion analysis system (Kim and Bae 2018). Results showed that the risk of loading and unloading clothes for side swing opening door exceeds the medium level of risk. Analysis of three-dimensional motion and virtual human model showed significant changes in the subjects'. Design changes such as clothe dryer paired with a top load washing machine modified to open up and close down by 30 degree etc. were suggested.

Blain-Moraes et al. (2012) designed and fabricated a manual washing machine to prevent contact between tap and hand. The machine employs the use of pedal operated clutch cable and a return spring to operate the water tap, while making use of pedal operated contact spring for the spraying of soap. The average human height was considered to make the machine ergonomically satisfactory, so as to make its usage more comfortable. Thus, ergonomic evaluation of manual operations among individuals using washing machine has been in vogue for more than a century (Blain-Moraes et al. 2012). The evaluation was based on the design of panel, height of the washing machine, etc. Discomfort or pain perceived on various regions of the

human body for individuals is yet to be researched. Thus, to overcome limitation in which the pain scale hasn't been analyzed, this study aims to analyze the ergonomic issues associated with washing machine users in south Indian population through RBG (Rehabilitation Bioengineering Group) Pain scale. This study also aims for innovative washing machines in terms of good usability, design, and comfort.

2 Methods and Materials

2.1 Subject Summary

An Ergonomics survey with the aid of a self-assessment questionnaire was conducted among 149 subjects (98 females and 51 males) in the age group of 16–80 years (the average age was 56 years). The average height of the users was found to be 95 cm while the average weight was 70 kg. The average hours spent using washing machine was 24 h per week. The survey was circulated among our friends and relatives using Google Forms.

2.2 Methods

A questionnaire was developed to explore the ergonomic issues associated with products with the following topics:

(1) Ergonomics of washing machine usage
(2) Inconveniences and difficulties faced by washing machine users.

Display design, panel design (Fig. 1), top, front-load designs (Bao et al. 2017) were investigated for musculoskeletal disorders (MSD) using the RBG (Rehabilitation Bioengineering Group) Pain score as shown in Fig. 2. RBG Pain score was analyzed in body, neck and shoulder, upper arm, low back, and knees regions.

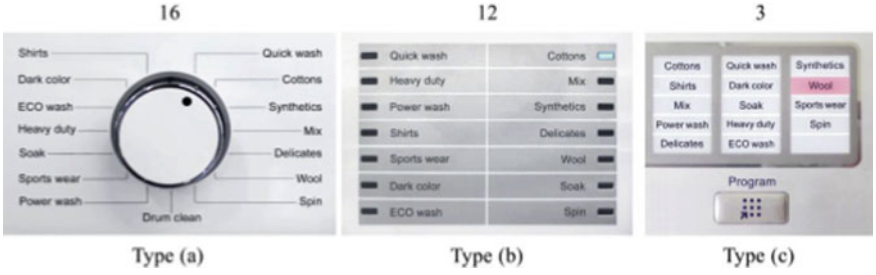


Fig. 1 Common types of panel design used in washing machine (Huang et al. 2018)

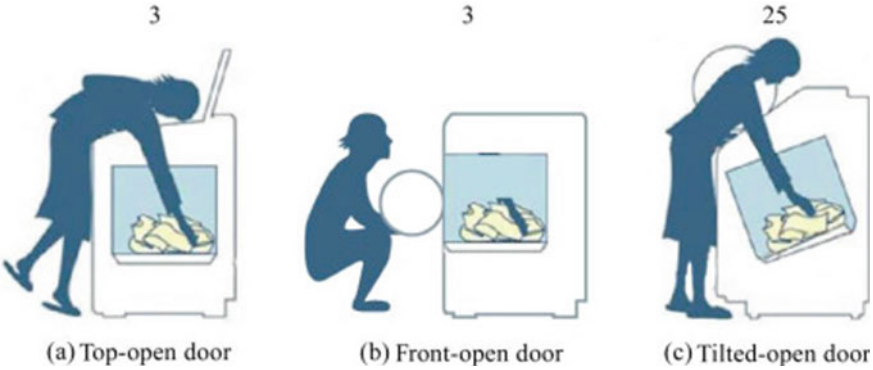


Fig. 2 Common types of washing machine doors (Huang et al. 2018)

During the survey, the participants were allowed to discuss related to the topics and express their opinions. This was very much helpful for the researchers to get a deeper understanding of users' ideas/issues faced.

A self-administered questionnaire was provided to check the overall discomfort score while using washing machine at body regions, neck, shoulder, upper arm, low back, and knee (Fig. 3).

Fig. 3 Typical regions of the body where the discomfort is experienced

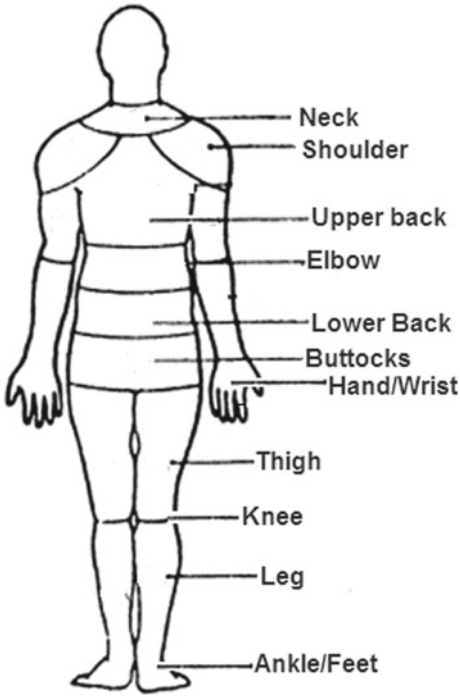


Table 1 Criteria for pain scale and score

Criteria	Score
No pain	0
Pain while more than average work out time	1
Mild pain	2
Moderate pain	3
Continuous pain	4
Severe pain	5

Pain scale analysis was used to estimate the internal consistency that is, how closely it is related to a set of items or as a group. To estimate the Pain scale, Cronbach's alpha test was used. Cornbach's alpha test is considered to be a measure of scale reliability. Here, we consider three categories of Cornbach's alpha test, (i) scores of 90 and above are considered as *best Score* and (ii) scores between 80 and 90 were considered as *better score* and scores between 70 and 80 were considered as *good score*. Cronbach's alpha test was performed mainly to check the reliability of the collected data. Reliability of the data is found to be 0.70. Thus, the collected data fall under good reliability score. Criteria for Pain scale and their score are depicted in Table 1.

Workers performing washing tasks using different types of washing machine design (Figs. 4 and 5) such as top open door, front open door, and titled open door machines were assessed.

Huang et al. (2018) concluded that people are much comfortable with tilted open loading machines. But, we have not considered tilting machines in our study (not

Fig. 4 Subject working with front-load washing

Fig. 5 Subject working with top open washing machine

much commonly used in India). Using our study, we find that the use of front open washing machine produces less pain when compared to top open machine. Figure 6 shows the mean value of RBG Pain score obtained from the Ergonomics survey of washing machine. Statistical results show that subjects who use top-loading washing

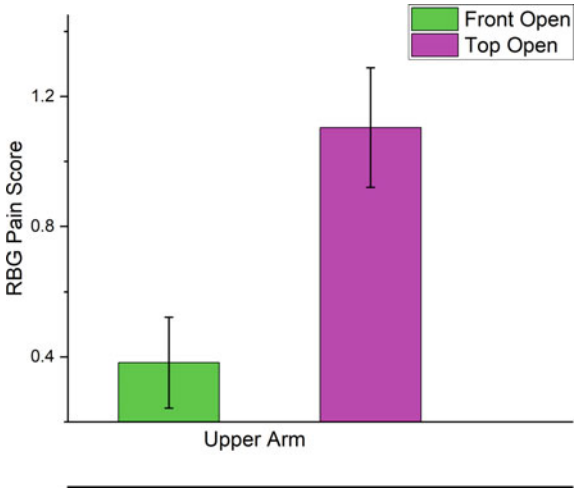


Fig. 6 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of loading design for upper arm region

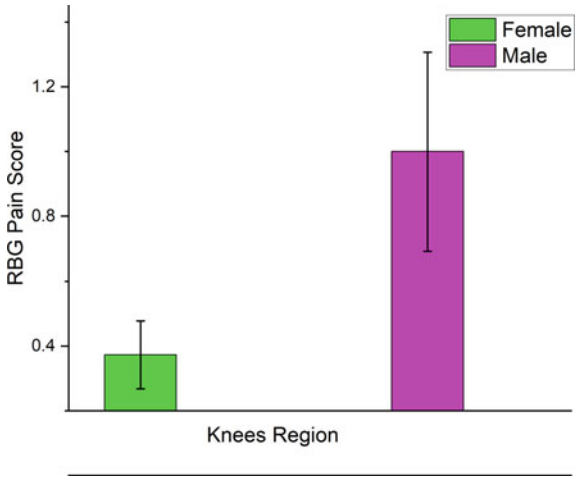


Fig. 7 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of gender (male vs) for knee region

machine have significantly ($p < 0.05$) high pain in the upper arm compared with those using front-loading washing machines as shown. While loading clothes in top open machine, people feel very high pain in the upper arm compared with those loading clothes in front open machine. In top loading machine, people have to stretch their hands while loading clothes, this may also cause pain in their upper arm.

Statistical result shows that male subjects have significantly ($p < 0.05$) high pain in the knee region compared with female subjects (as shown in Fig. 7). While using washing machine and loading clothes, male subjects have high pain in their knee region than female subjects. This may be due to the multitasking ability of the females, which makes them experience very less pain during the washing activity compared with males.

Huang et al. (2018) identified that people feel comfortable with simplified and normal panel designed machines with less number of buttons. However, in the present study, we find that panel with full button type of washing machine produce less pain. Figure 8 shows that among the different panel designs, people who use washing machine with knob design have significantly ($p < 0.05$) high pain in body, neck, and shoulder regions as compared with panel design with jumping lights and panel with full buttons washing machine. People who use knob design washing machine have to strain more than the other types of washing machines. Similarly, people who use washing machines with jumping lights feel light pain in their body and knee regions. This is because people have to give more force to press the jumping lights buttons. Thus, washing machine with full button panel is comfortable to use as it causes less pain compared with the other two types of panel.

The BG Pain score was significantly ($p < 0.05$) high in body region and upper arm for touch screen type button design when compared with plastic and rubber designs as shown in Fig. 9. Those who use touch screen types of buttons experience more pain in both body and upper arm regions. This is because in touch screen types, people have to give more force on their finger, which causes more pain in body and upper

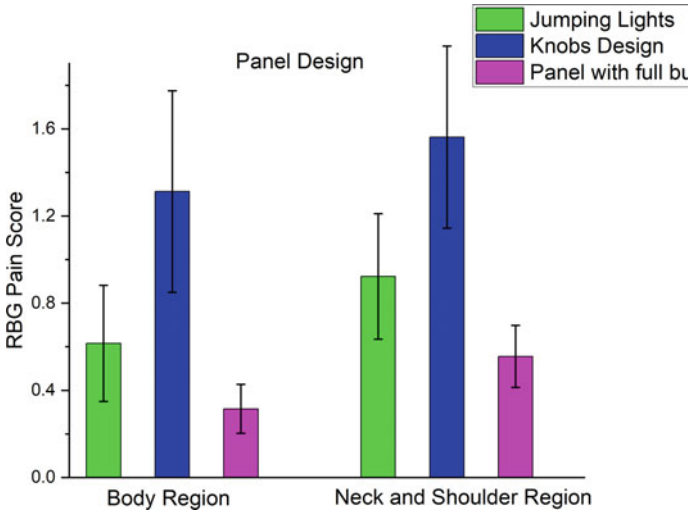
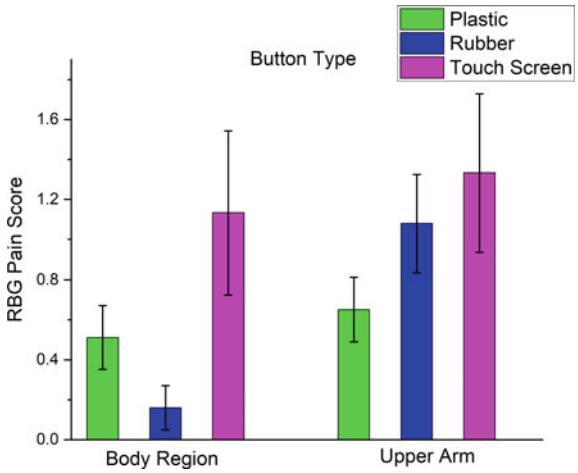


Fig. 8 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of panel design

Fig. 9 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of button designs



arm regions, more so when water droplets fall on the touch screen as it requires more force than usual force in addition to slipping effect of fingers. On comparing plastic and rubber type buttons, plastic button causes little pain in body region compared with rubber button and similarly rubber button experiences high pain in upper arm region compared to plastic buttons. Thus, from the survey, it is clear that plastic buttons and rubber button experience less pain compared with touch screen.

3 Conclusion

The main aim of this research work was to find the ergonomic issues associated with washing machine users in South Indian Region. Our study result provides clear evidence that the use of washing machines leads to MSD disorders. This study also explores the people's preferences, demands, and suggestions for washing machines. Since washing machines are one among the most commonly used household appliances, the results of this study can also contribute to further improve the design of many other such household appliances. This study also reveals that the ability of females to perform multiple tasks makes them experience less pain when using washing machine. Based on the findings of the study, it is recommended that front loading with rubber button design is an appropriate ergonomics design for washing machines. It is important for engineering designers (product designers and engineers in the household appliances industry) to consider functional capabilities and limitations of users (all genders and all age groups) when designing products for daily use and daily living environments.

References

Balasubramanian V, Jagannath M, Adalarasu K (2014) Muscle fatigue based evaluation of bicycle design. Appl Ergon 45(2):339–345

Balasubramanian V, Adalarasu K, Regulapati R (2008) Comparing stationary standing with an intermittent walking posture during assembly operations. Hum Factors Ergon Manuf 18(6):666–677

Bao W, Gong RH, Ding X, Xue Y, Li P, Fan W (2017) Optimizing a laundering program for textiles in a front-loading washing machine and saving energy. J Clean Prod 148:415–421

Barrett J, Kirk S (2000) Running focus groups with elderly and disabled elderly participants. Appl Ergon 31(6):621–629

Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, Garry PJ, Lindeman RD (1998) Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 147(8):755–763

Beniuk C, Ward JR, Clarkson PJ (2011) Applying inclusive design principles in the assessment of healthcare services. In: European design 4 health conference, Sheffield, UK

Blain-Moraes S, Schaff R, Gruis KL, Huggins JE, Wren PA (2012) Barriers to and mediators of brain-computer interface user acceptance: focus group findings. Ergonomics 55(5):516–525

Ejiko S, Olorunnishola AA, Osayomi PA (2020) Ergonomic development of manual hand washing machine to ameliorate the deadly effect of COVID 19 pandemic. IARJSET 7(7):6–16

Fakhriza Z, Iqbal M, Rahayu M (2017) Design improvement of automated gallon washing machine to minimize musculoskeletal disorders (MSDs) in CV Barokah Abadi using ergonomic function deployment (EFD) approach. IOP Conf Ser Mater Sci Eng 277(2017):012021

Huang H, Yang M, Taifeng L (2018) Ergonomic analysis of washing machines for elderly people: a focus group-based study. Int J Ind Ergon 68:211–221

Ishihara S, Ishihara K, Nagamachi M, Sano M, Fujiwara Y et al (2008) Developments of home electric appliances with Kansei ergonomics: Sanyo cases: Kansei and kinematic considerations on washer-dryer and electric shaver. In: Proceedings of 11th QMOD conference. Quality Management and Organizational Development Attaining Sustainability from Organizational Excellence to Sustainable Excellence, pp 351–360

Keiko I, Shigekazu I et al (2015) Development of a washer-dryer with Kansei ergonomics. Eng Lett 18:3, EL_18_3_05
Kim DH, Bae SH et al (2018) Biomechanical study on the convenience of loading and unloading laundry in clothes dryer. Int J Precis Eng Manuf 19(6):907–915