European Journal of Pediatrics (2021) 180:3483–3489
https://doi.org/10.1007/s00431-021-04142-8

ORIGINAL ARTICLE

Handgrip strength cut-off points for early detection of cardiometabolic risk in Chilean children

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Received: 13 April 2021 / Revised: 28 May 2021 / Accepted: 2 June 2021 / Published online: 9 June 2021

Abstract
The aim of this study was to determine whether handgrip strength is associated with cardiometabolic risk in children. The secondary aim was to establish sex-specific handgrip strength cut-off points for early detection of cardiometabolic risk. A total sample of 452 Chilean children (267 girls and 185 boys) aged 7–9 years old was analyzed. Muscle fitness was measured by an adjustable dynamometer and normalized by body mass (i.e., handgrip strength/body mass). Sex-specific cardiometabolic risk scores were computed as the sum of the waist-to-height ratio (Equation 1) or waist circumference (Equation 2) and insulin, triglycerides, high-density lipoproteins, and glycemia levels. Receiver operating curve (ROC) analyses were performed to identify those with cardiometabolic risk scores > 1 standard deviation above the mean. ROC analyses showed a significant discriminating accuracy of normalized handgrip strength in identifying cardiometabolic risk in boys (≤ 0.33) and girls (≤ 0.40) using both equations. The highest sensitivity was offered by Equation 2 for boys [46%; 95% CI (32–59%)] and for girls [71%; 95% CI (60–80)]. The greatest specificity was also offered by Equation 2 for boys [82%; 95% CI (74–88)] and girls [63%; 95% CI (55–70)]. Since the values obtained by ROC analyses are low (especially in boys), caution is warranted regarding the strength of the existing evidence base.

Conclusion: These specific cut-off points according to sex for possible cardiometabolic risk could be used by Chilean health professionals and school staff as an initial assessment in the field setting.

What is known

• *There is strong evidence for the importance of muscular fitness during childhood and adolescence for cardiometabolic risk.*
• *There has been no research to establish minimum handgrip strength capacity levels to predict cardiometabolic risk among Chilean children.*

What is new

• *Cut--off points for handgrip strength relative to body mass to identify cardiometabolic risk in Chilean children are 0.33 in boys and 0.40 in girls.*
• *The early use of these cut-off points and its appropriate identification could have benefits of preventive and diagnostic therapeutic intervention and as a starting point to define adequate levels of handgrip strength.*

Keywords Physical fitness · Metabolic syndrome · Muscular fitness · Biomarkers

Communicated by Gregorio Paolo Milani

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Introduction

Cardiometabolic risk is defined as a cluster of dichotomous or continuous cardiometabolic abnormalities that comprises glucose intolerance, insulin resistance, abdominal obesity, dyslipidemia, and hypertension, all of them well-known risk factors for cardiovascular disease [1]. Cardiometabolic risk scores in childhood could have important intermediate or preclinical outcomes to be assessed prior to adult disease onset, thereby providing opportunities for prevention [2].

On the other hand, there is growing evidence that has highlighted the importance of muscle fitness as a marker of health [3]. In particular, a clinically feasible measure of muscle fitness handgrip strength test can predict cardiovascular, respiratory, cancer [4], and all-cause mortality [5] in adults. It is also associated with better cardiometabolic risk profiles among children and adolescents [6, 7].

In order to determine cardiometabolic risk, the sum of some risk factors (i.e., dyslipidemia, glucose intolerance, hypertension, and total and or abdominal obesity) has been suggested as a practical tool [1] even in children [8, 9]. Since cardiometabolic risk and many of its characteristics stem from childhood and can persist and increase in adulthood, early detection and diagnosis are required to develop more effective prevention programs. In this regard, and in relation with muscular fitness, Fraser et al. [10] suggested that the promotion of muscular fitness among children might provide additional protection against developing adult metabolic syndrome.

Research in the USA [3], Colombia [11], Spain [12], and several European countries from the HELENA study [13] has established cut-off points to detect cardiometabolic risk in young people. Although scientific evidence concerning the role of muscular fitness in preventing cardiometabolic risk factors in several populations does exist, there is no study which establishes minimum handgrip strength capacity levels to predict cardiometabolic risk among Chilean children. This is of the utmost importance, as children from Chile seem to have lower levels of handgrip strength compared to children from the above-mentioned countries [14]. The use of these cut-offs could help to formulate specific strategies to promote the future health of Chilean children. Hence, the aim of this study was to determine whether handgrip strength is able to detect cardiometabolic risk in Chilean children, and to establish sex-specific cut-off points for early detection.

Material and methods

Design and participants

The study sample was drawn from children enrolled in the "Growth and Obesity Chilean Cohort Study," aimed to assess the association of early growth and development with adiposity and cardiometabolic risk. In order to carry out this study, we included 452 healthy children (267 girls and 185 boys) aged 7–9 years old selected randomly from original study. The inclusion criteria of the study was as follows: 7–9-year-old attending Chilean National Nursery School Council Program nursery schools from the south area of Santiago (Chile); singletons; gestational age 37–42 weeks; birth weight ≥ 2500 g (data retrieved from medical archives); no physical or psychological conditions that could severely affect growth [15]; and blood data available.

Parents or guardians signed a previously-approved informed consent by the Ethical Committee of the Institute of Nutrition and Food Technology (Act no. 19, 2009).

Procedures

Weight was gauged with an electronic scale (Body Composition Analyzer TANITA BC-418) with a 0.1 kg accuracy and 220 kg max measurement. Children were measured in underwear, placing their feet in the center of the scale. Height measurement was done with a portable stadiometer (SECA 222®) ranging between 0 and 200 cm with 1 mm precision, using the Frankfurt standard [16]. Nutritional status was determined using body mass index (BMI) and BMI z-score [17]. BMI was calculated using weight (kg)/height $(m)^2$. Waist circumference (WC) was measured with an inextensible tape (SECA®), over the iliac crest [18]. Finally, waist circumference and height were used to calculate the waist-to-height ratio (WHtR).

Muscle fitness was measured using the handgrip strength test. For this purpose, an adjustable hand grip digital dynamometer regulated according to the sex and hand size of each participant was used (Baseline 12-0286®; 100 g accuracy) and results were expressed in kg. The handgrip test was performed twice by each child with their arms outstretched, squeezing the dynamometer as hard as possible, for at least 2 s. One minute of recovery between squeeze was measured (alternating right and left hand). The test was performed twice and the maximum score for each hand was recorded in kilograms. The average of the scores achieved by left and right hands was used in the analysis [19]. To avoid the potential biasing effect of body weight on the estimation of handgrip strength [3], we adjusted handgrip strength for body weight (kg).

Blood samples were obtained between 08:30 and 10:30 after an 8-h overnight fast. Part of the blood was collected in test tubes with no added anticoagulant so it could clot for approximately 2 h, as this was designated for serum separation. Blood was centrifuged at 3000 rpm for 15 min and the collected serum was divided into aliquots and stored at – 80 °C. Ten milliliter venous blood was collected; serum glucose was assessed using a commercial kit by GOD-PAP (Clinical Chemistry Applied SA) enzymatic colorimetric method.

Insulin was measured by radioimmunoassay (RIA) (RIA DCP Diagnostic Products Corporation LA USA). Basal insulin sensitivity was estimated by the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) (fasting insulin (mIU/dl) * fasting glucose (mmol/l)/22.5) [20]. High-density lipoprotein cholesterol (HDL) and triglycerides were determined by dry analytical methodology (Vitros, Johnson & Johnson, Clinical diagnostics Inc). HDL values were multiplied by − 1 since it is inversely related to metabolic risk.

Finally, continuous cardiometabolic risk scores were defined by the following two equations using different anthropometric parameters: (i) Equation 1, calculated as the sum of Z score of WHtR-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z; and (ii) Equation 2, calculated as the sum of Z score of WC-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z. Children with a cardiometabolic risk score + 1 standard deviation (SD) above the mean were identified as having cardiometabolic risk. This choice is justified by previous findings [21], since this criterion is more conservative than higher cut-off points that increase not only odds ratios but also confidence intervals.

Statistical analysis

Age, anthropometric data, biochemical assessments, and handgrip strength characteristics of the study sample are shown as means and SD (for normally distributed variables). The assumption of normality was demonstrated by histograms and Q-Q plots. Differences were analyzed by Student's *t* test or Mann-Whitney *U* test. There were no missing data.

Cut-off point values were calculated arithmetically from the receiver operating curves (ROC), considering the point on the ROC curve with the lowest value through the following formula: $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$. The positive likelihood ratio LR (+) and the negative likelihood ratio LR (−) were used to analyze the potential diagnostic accuracy of the normalized handgrip strength (by body weight) to discriminate between low and high cardiometabolic risk. This ratio assesses the goodness of fit of two competing statistical models based on the ratio of their likelihood, namely one found by maximizing over the entire parameter space and one found after imposing some constraint. The area under the curve (AUC) and 95% confidence interval (CI) were calculated. The AUC denotes the capability of the test to appropriately categorize children with a high cardiometabolic risk. The AUC values can range between 0.5 (worthless test) and 1 (perfect test). The classification error was non-differential and therefore the ROC curve analyses did not have co-variates.

The assumptions of outliers, collinearity, independent errors, random normal distribution of errors, homoscedasticity and linearity, and non-zero variances were tested, and all of these conditions were met. Finally, a multiple lineal regression analysis was used to determine the association between low level of normalized handgrip strength derived from the ROC analysis with anthropometric, biochemical parameters, and cardiometabolic risk scores.

All the analyses were performed by the software Statistical Package for the Social Sciences (SPSS) for Windows in its version 25.0 (SPSS, Chicago, Illinois, USA). A *p* value of 0.05 was set up to indicate statistical significance.

Results

Table 1 shows the characteristic of the study participants. A total of 452 children aged 7–9 years were included in the final analysis (59% girls). Girls were older than boys. Overall, boys had higher levels of glycaemia than girls ($p < 0.05$). No statistically significant differences were found for absolute handgrip strength and normalized handgrip strength between sexes and ages (data not shown). Similarly, we did not find sex differences for WHtR, WC, and BMI.

ROC analyses revealed a statistically significant moderate discriminatory accuracy in detecting cardiometabolic risk in boys (Equation 1, AUC = 0.658, 95% CI 0.570–0.747; Equation 2, AUC = 0.666, 95% CI 0.578–0.754) and girls (Equation 1, AUC = 0.675, 95% CI 0.607–0.744; Equation 2, AUC = 0.693, 95% CI 0.626–0.761) (Fig. 1). The suggested cut-off points of normalized handgrip strength values at these points for Equation 1 and Equation 2 were 0.33 in boys and 0.40 in girls, respectively (Table 2).

Table 3 shows the association between low level of normalized handgrip strength derived from the receiver operating characteristic curve analysis with anthropometric, biochemical parameters, and cardiometabolic risk scores. Overall, children with low levels of normalized handgrip strength have higher values of BMI z-score, WC, WHtR, insulin, triglycerides, triglycerides/HDL ratio, HOMA-IR, and cardiometabolic risk determined by both equations.

Discussion

Our study identified cut-off points relating handgrip strength to cardiometabolic risk in Chilean children aged 7–9 years. This research reinforces the existence of a muscle threshold associated with cardiometabolic health in young population.

Previous studies have established different cut-off points to detect cardiometabolic risk in young populations. For example in a Latin-American population from Colombia, Ramírez-Vélez et al. [11] proposed a cut-off point of 0.37 and 0.36 for boys and girls aged 9–12.9 years, respectively. The present study showed that the optimal cut-off for our population was 0.33 for boys (45 to 46% of sensitivity and 82% of specificity) and 0.40 for girls (68 to 71% of sensitivity and 61 to 63% of specificity), with only small differences between both

Table 1 Characteristics of study participants ($n = 452$)

Variables	Boys (n = 185; 40.9%)	Girls (n = 267; 59.1%)	$p^{ǂ}$
Age (years)	7.8 ± 0.5	7.9 ± 0.4	0.002
Height (cm)	126.6 ± 5.6	127.1 ± 5.8	0.370
Body weight (kg)	27.9 (7.6)	28.2 (8.1)	0.223
Body Mass Index (kg/m^2)	17.1 (3.2)	17.4 (3.9)	0.164
Body Mass Index (z-score)	1.00 (1.76)	0.91 (1.59)	0.942
Waist Circumference (cm)	59.2 (9.4)	60.4 (11.6)	0.161
Waist-to-Height ratio	0.47 (0.05)	0.48 (0.08)	0.137
Handgrip strength (kg)	11.2 (2.8)	11.2 (3.2)	0.143
Normalized handgrip strength*	0.40 (0.14)	0.41 (0.16)	0.657
Glycemia (mg/dl)	90.2 ± 6.2	88.7 ± 6.5	0.002
Insulin (uU/dl)	5.10 (0.6)	5.20 (0.7)	0.140
HDL (mg/dl)	49.6 ± 14.4	50.1 ± 12.3	0.672
Triglycerides (mg/dl)	88.0 (51.5)	87.0 (49.0)	0.619
HOMA-IR	1.14 (0.2)	1.13 (0.2)	0.743
Equation 1	− 0.24 (3.06)	− 0.12 (3.32)	0.854
Equation 2	− 0.32 (3.18)	− 0.09 (3.29)	0.840

Data expressed as mean ± standard deviation or median (interquartile range)

* Absolute handgrip strength normalized by body weight

ǂ Differences between sexes were determined by the Student's *t* test for variables with normal distribution), or by Mann-Whitney *U* test for variables without normal distribution

HDL high-density lipoprotein. Equation 1 calculated as the sum of Z score of waist-to-height ratio-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z; Equation 2 calculated as the sum of Z score of waist circumference-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z

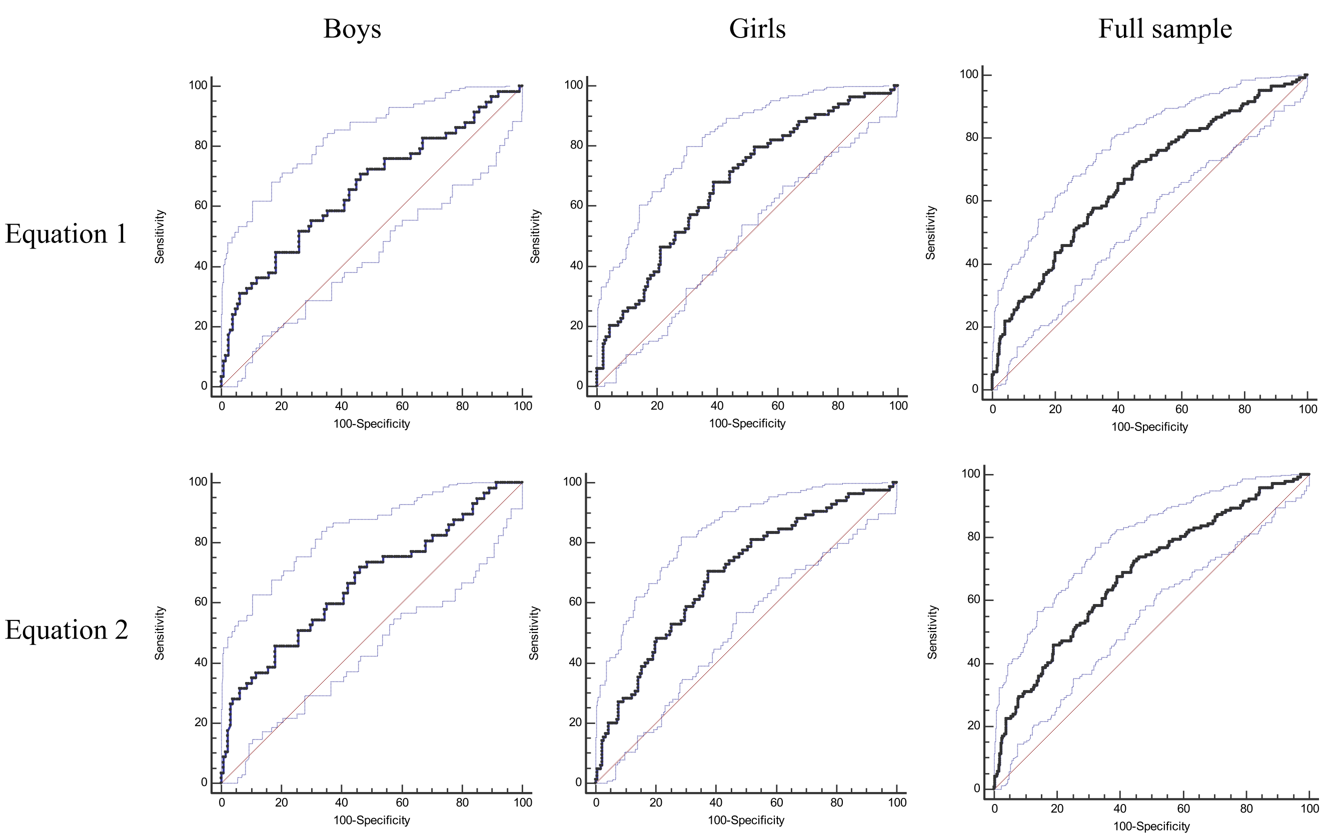

Fig. 1 Receiver operating characteristic (ROC) curve of the normalized handgrip strength [measured as (grip strength in kg)/(body mass in kg)], to detect cardiometabolic risk in both sexes and full sample

Table 2 Cut-off points between area under curve, sensitivity, and specificity for normalized handgrip strength by body weight to detect cardiometabolic risk by different equations according to sex

Parameters	Equation 1	Equation 2
Boys		
Area under curve (CI 95%)	0.658 (0.570 - 0.747)	0.666 (0.578 - 0.754)
SE	0.0454	0.0451
P value	0.0005	0.0002
Youden index J	0.2672	0.2765
Optimal cut-off	≤ 0.33	≤ 0.33
Sensitivity (CI 95%)	45 (32–58)	46 (32–59)
Specificity (CI 95%)	82 (74–87)	82 (74–88)
(+) Likelihood ratio (CI 95%)	2.48 (1.6–3.9)	2.54 (1.6–4.0)
(–) Likelihood ratio (CI 95%)	0.67 (0.5–0.9)	0.66 (0.5–0.9)
Prevalence disease (%)	31	31
Girls		
Area under curve (CI 95%)	0.675 (0.607–0.744)	0.693 (0.626–0.761)
SE	0.0351	0.0346
P value	< 0.0001	< 0.0001
Youden index J	0.2906	0.3323
Optimal cut-off	≤ 0.40	≤ 0.40
Sensitivity (CI 95%)	68 (57–78)	71 (60–80)
Specificity (CI 95%)	61 (54–68)	63 (55–70)
(+) Likelihood ratio (CI 95%)	1.75 (1.4–2.2)	1.89 (1.5–2.4)
(–) Likelihood ratio (CI 95%)	0.53 (0.4–0.7)	0.47 (0.3–0.7)
Prevalence disease (%)	31	32
Full sample		
Area under curve (CI 95%)	0.667 (0.613–0.722)	0.681 (0.628–0.735)
SE	0.0278	0.0274
P-value	< 0.0001	< 0.0001
Youden index J	0.2597	0.2857
Optimal cut-off	≤ 0.41	≤ 0.40
Sensitivity (CI 95%)	71 (63–78)	68 (59–75)
Specificity (CI 95%)	55 (49–60)	61 (55–66)
(+) Likelihood ratio (CI 95%)	1.57 (1.3–1.9)	1.73 (1.4–2.1)
(–) Likelihood ratio (CI 95%)	0.53 (0.4–0.7)	0.53 (0.4–0.7)
Prevalence disease (%)	31	31

CI confidence interval, *SE* standard error. Equation 1 calculated as the sum of Z score of waist-to-height ratio-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z; Equation 2 calculated as the sum of Z score of waist circumference-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z

Table 3 Association between low level of normalized handgrip strength derived from the receiver operating characteristic curve analysis with anthropometric, biochemical parameters, and cardiometabolic risk scores

Parameter	B	95% CI	Beta	*P* value
Body mass index (z-score)	1.323	1.122 to 1.524	0.544	< 0.001
Waist circumference (cm)	9.073	7.852 to 10.295	0.587	< 0.001
Waist-to-height ratio	0.055	0.046 to 0.064	0.525	< 0.001
Glycemia (mg/dl)	1.083	− 0.203 to 2.370	0.081	0.099
Insulin (uU/dl)	0.400	0.147 to 0.654	0.152	0.002
HDL (mg/dl)	− 1.860	− 4.502 to 0.781	− 0.068	0.167
Triglycerides (mg/dl)	9.684	1.477 to 17.89	0.114	0.021
Triglycerides/HDL ratio	0.287	0.025 to 0.548	0.105	0.032
HOMA-IR	0.108	0.042 to 0.173	0.158	0.001
Equation 1	1.897	1.366 to 2.428	0.330	< 0.001
Equation 2	2.028	1.493 to 2.564	0.347	< 0.001

Analysis adjusted by age and sex

Equation 1 calculated as the sum of Z score of waist-to-height ratio-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z; Equation 2 calculated as the sum of Z score of waist circumference-z, insulin-z, triglycerides-z, HDL-z, and glycaemia-z equations. However, we found lower sensitivities and specificities than the above-mentioned study [11]. Among girls, we found higher cut-off points than children from Colombia [11] and Spain [12]. One possible reason for these discrepancies could be explained by the different variables used by these authors to compute cardiometabolic risk (e.g., skinfolds thickness, systolic blood pressure).

Despite the previous evidence on the role of muscular fitness in children and youth in preventing cardiometabolic risk [6, 7], the accurate factors that could explain the protective effect of muscular fitness on the cardiometabolic risk in young population have not been fully determined yet [11]. One possible explanation of the apparently protective role of muscular fitness in children and adolescents could be a consequence of the changes caused by puberty, as Steene-Johannessen et al. hypothesized [22]. Furthermore, these authors, as well as Castro-Piñero et al. [12], also described a relationship in prepubertal children and both sexes. Another plausible factor explaining why muscular fitness could influence insulin resistance can be the stimulation of proteins in the insulin-signaling cascade [23]. In order to strengthen this idea, an experimental study has reported that improving muscular fitness through resistance training promotes an increased insulin sensitivity [24].

This study contains some limitations that must be stated. Firstly, due to the nature of this study (cross-sectional), it is not possible to establish cause-effect relationships. Secondly, the current lack of consensus in youth regarding the definition of cardiometabolic risk might limit our results. For this reason, we decided to incorporate three different continuous equation methods (including WHtR and WC) to ensure that the proposed cut-off points were as accurate as possible, regardless of the method adopted. Thirdly, muscle fitness was measured by the handgrip strength test, which may not represent overall muscular fitness. Lastly, since adjustment for potential confounding variables is not possible in ROC analysis, data could not be adjusted. This study has several strengths too. On the one hand, to the best of our knowledge, this is the first study which establishes cut-off points for early detection of cardiometabolic risk in Chilean children. Furthermore, the current findings have meaningful relevance, since they offer knowledge about the extent to which different handgrip strength thresholds can reflect cardiometabolic risk in children.

Our research identifies some cut-off points of normalized handgrip strength linked to cardiometabolic risk in Chilean children aged 7–9 years old. However, since the values obtained by ROC analyses are low (especially in boys), caution is warranted regarding the strength of the existing evidence base. Nevertheless, these cut-off points could be a useful tool to categorize children at possible cardiometabolic risk. The early use of these cut-off points and their appropriate identification could have benefits in terms of preventive and diagnostic therapeutic intervention and as a starting point to define adequate levels of handgrip strength in relation to body mass and offer feedback to parents, teachers, and health professionals.

Abbreviations AUC, Area under curve; BMI, Body mass index; HDL, High-density lipoprotein cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; LDL, Low-density lipoprotein cholesterol; RIA, Radioimmunoassay; ROC, Operating characteristic curve; WC, Waist circumference; WHtR, Waist-to-height ratio

Acknowledgments AGH is a Miguel Servet Fellow (Instituto de Salud Carlos III-FSE–CP18/0150). RR-V is funded in part by a Postdoctoral Fellowship Resolution ID 420/2019 of the Universidad Pública de Navarra.

Authors' contributions Conceptualization, A.G.-H. and R.R.-V.; methodology, A.G.-H. and R.R.-V.; software, R.R.-V.; validation J.L.-G., G.W., A.G.-H. and R.R.-V.; formal analysis, A.G.-H. and R.R.-V.; investigation, G.W.; resources, A.G.-H. and R.R.-V.; data curation, A.G.-H. and R.R.-V.; writing—original draft preparation, J.L.-G. and A.G.-H.; writing—review and editing, J.L.-G., A.G.-H. and R.R.-V.; visualization, G.W.; supervision, G.W.; project administration, G.W.; funding acquisition, G.W.

Funding N/A.

Data availability The data presented in this study are available on request from the corresponding author. The data are not publicly available because they belong to minors.

Code availability N/A.

Declarations

Conflict of interest The authors declare no conflict of interest.

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