JIDR Journal of Intellectual Disability Research
Published on behalf of mencap and in association with IASSID

Journal of Intellectual Disability Research doi: 10.1111/jir.13069

VOLUME 67 PART 11 pp 1124–1135 NOVEMBER 2023

Cut-off points for isometric handgrip and low limb explosive strength in relation to indicators of overweight/obesity in people with intellectual disabilities: analysis by age groups

P. Ferrero-Hernández,[1] **C. Farías-Valenzuela,**[2,6] **G. Ferrari,**[3] **S. Espoz-Lazo,**[4] **S. Álvarez-Arangua**[5] **& P. Valdivia-Moral**[6]

1 *Escuela de Pedagogía en Educación Física, Facultad de Educación, Universidad Autónoma de Chile, Santiago, Chile*
2 *Instituto del Deporte, Universidad de Las Américas, Santiago, Chile*
3 *Sciences of Physical Activity, Sports and Health School, University of Santiago of Chile (USACH), Santiago, Chile*
4 *Facultad de Educación y Ciencias Sociales, Instituto del Deporte y Bienestar, Universidad Andres Bello, Las Condes, Santiago, Chile*
5 *Exercise and Rehabilitation Sciences Institute, School of Physical Therapy, Faculty of Rehabilitation Science, Universidad Andres Bello, Santiago, Chile*
6 *Department of Didactics of Musical, Plastic and Corporal Expression, Faculty of Education, University of Granada, Granada, Spain*

Abstract

Background The prevalence of overweight/obesity has been increasing globally and in people with Intellectual Disabilities (IDs), this problem is exacerbated even more, which added to a low physical condition that contributes to the deterioration of functionality and increases the risk of developing chronic diseases in the course of life. Therefore, the aim of this study was to establish cut-off points for levels of isometric handgrip and low limb explosive strength in children, adolescents and adults, which identify overweight/obesity in people with IDs and their respective associations.

Methods The sample was made up of 131 individuals with IDs, belonging to four special and community educational centres in the city of Santiago, Chile. Body mass index (BMI) and waist-to-height ratio (WHR) were used as indicators of overweight/obesity. Handgrip strength was used as a measure of isometric strength, and countermovement jump was used as a measure of low limb explosive strength. For the comparison of variables by age group, the analysis of Ancova, Kruskal–Wallis and chi-square tests were used. The total area under the receiver operating characteristic curve of isometric handgrip and low limb explosive strength was identified as an indicator of overweight/obesity according to age groups. A logistic regression model was used to quantify the effect that strength categories below the cut-off point have on the risk of overweight and obesity.

Results Significant differences were observed between the age groups for body weight, height, BMI and WHR, as well as in the levels of absolute handgrip strength and vertical jump with countermovement ($P \leq 0.05$). Children showed the lowest cut-off points for absolute and relative strength. The adolescent group showed the highest cut-off points for relative strength and countermovement jump and adults showed the highest value for absolute strength as

Correspondence: Dr. Pedro Valdivia-Moral, Department of Didactics of Musical, Plastic and Corporal Expression, Faculty of Education, University of Granada, 18071 Granada, Spain (e-mail: pvaldivia@ugr.es)

indicators of overweight/obesity. Different associations between cut-off points with BMI and WHR were found.
Conclusions Adolescents showed the highest cut-off point for relative strength and countermovement jump, and adults showed the highest value for absolute strength, according to overweight/obesity indicators (BMI and WHR). It is suggested to adjust resistance training programmes according to age categories for the prevention of overweight/obesity in people with IDs.

Keywords countermovement jump, functional capacity, handgrip strength, intellectual disability, muscle strength, obesity, overweight

Introduction

Overweight and obesity are growing problems worldwide that affect children, adolescents and adults and are associated with decreased life expectancy (Engin 2017). In this sense, people with intellectual disabilities (IDs) have a higher prevalence of obesity and associated chronic diseases than people without disabilities (Kelly *et al.* 2022). This condition exposes them to the development of metabolic and cardiovascular diseases such as diabetes and heart disease (Doody & Doody 2012) and can be explained by multifactorial causes such as the presence of comorbidities, eating habits, decreased energy expenditure at rest (Bertapelli *et al.* 2016) and lower levels of physical activity in comparison with the general population (Borland *et al.* 2020). The foregoing is transversal to all ages, affecting negatively the development of daily activities and their quality of life. In children, the prevalence of overweight/obesity is almost double compared with children without disabilities (Segal *et al.* 2016), while throughout adulthood, it shows a higher figure, reaching an increase in the prevalence of overweight of 22–22.5% and obesity of 23.8–38% in adolescents and adults with Down syndrome, respectively, compared with the population without disabilities (Hsieh *et al.* 2014; Krause *et al.* 2016), which translates into an increased risk of health conditions and cardiometabolic diseases in the course of life. In general, people with IDs have shorter height (Diets *et al.* 2019), a condition that is related to a higher waist-to-height ratio (WHR), which is considered a better indicator than waist circumference to assess abdominal obesity in individuals of short stature, with developmental disorders (Kasagi 2021) and as a predictor of arterial hypertension (Wyszyńska *et al.* 2020) in schoolchildren with IDs (Real de Asua *et al.* 2014). In addition, people with IDs have lower levels of physical fitness and functional limitations than people without disabilities (Silva *et al.* 2017). Among the affected physical fitness, a reduction in strength production levels is observed compared with groups without disabilities, which leads to a general deterioration of health and a reduction in life expectancy (Zghal *et al.* 2019). Likewise, this loss of muscle strength observed in people with IDs is strongly related to the decline in physical and functional capacity (Carmeli *et al.* 2012).

Evidence has shown positive effects of physical activity on body composition, including improvements in body mass index (BMI), waist circumference and body fat percentage, as well as changes in body weight control in children, adolescents and adults with IDs (Martínez-Espinosa *et al.* 2020). For its part, muscle strength has been associated with a decrease in cardiovascular risk, showing that higher levels of strength are associated with lower waist circumference and triglycerides in children, adolescents and adults (De Lima *et al.* 2021). In fact, higher levels of upper and lower body muscle strength in general population are associated with a lower risk of mortality (García-Hermoso *et al.* 2018). Muscular endurance programmes specifically have been shown to be effective and provided benefits in improving functionality, cardiorespiratory fitness, mobility and performance in activities of daily living (Obrusnikova *et al.* 2022), including skills related to work in people with IDs (Smail & Horvat 2006). In this context, handgrip dynamometry tests have been validated as tools for assessing functional capacity in individuals with IDs, associated with maximum isometric strength (Farías-Valenzuela *et al.* 2019). In addition, the countermovement jump (CMJ) has been used as a measure of joint mechanical power and neuromuscular activation in people with IDs, suggesting that this population could benefit from plyometric training programmes (Hassani *et al.* 2014).

Previous studies have linked muscle strength training with improvements in maximal strength levels and functional mobility in children and adolescents (Sugimoto *et al.* 2016), as well as positive changes in body composition in adults with IDs (Jacinto *et al.* 2021). However, cut-off points for specific strength levels by age group have not been established considering the characteristics of this population. The aim of this study was to establish cut-off points for levels of isometric handgrip and low limb explosive strength that identify overweight/obesity in children, adolescents and adults with IDs and their respective association.

Methods

Design and participants

This research corresponds to a descriptive, non-experimental and cross-sectional study. The sample consisted of 131 individuals (43 females and 88 males), mean age of 15.6 [standard deviation (SD): 7.2] with mild and moderate IDs, belonging to two special educational centres and two out-of-school social groups of disabled people in the city of Santiago, Chile. The sample data were extracted between the months of August and November 2021, in the context of the development of the project 'LudoInclusión 19', belonging to the Vice-Rector's Office for Community Outreach (VIME, in Spanish) of University of Santiago of Chile. Prior to the study, authorisation was obtained from the authorities of the involved centres, in addition to the respective informed consent of the parents and/or guardians, who voluntarily agreed to accept the participation of their pupils. The study complies with the guidelines set forth in the Declaration of Helsinki (2014) and has the approval of the ethics committee of the University of Granada, code 2052/CEIH/2021.

The inclusion criteria considered for the selection of the participants were diagnosis of mild or moderate ID, obtained through the 'Wechsler Intelligence Scale for Children-III' or WISC III (Ramírez & Rosas 2007) in the case of minors' age (<18 years) and by the WAIS IV or 'Wechsler Adult Intelligence Scale-IV' (Rosas *et al.* 2014) in the case of >18 years, whose information was obtained from the clinical records of each centre, and having independent autonomy and mobility. The exclusion criteria were having some type of motor disability or being dependent on a wheelchair. The age categories were classified into the following groups: (1) children: 5–11 years; (2) adolescents: 12–17 years; and (3) adults: 18–45 years. No specific syndromes were considered for the study; the diagnosis was based on the IQ scale results only.

Indicators of overweight/obesity

The indicators of overweight/obesity used in the present study were body weight (kilograms), height (metres), BMI (kilograms per square metre) and WHR (Jabłonowska-Lietz *et al.* 2017; Soheilipour *et al.* 2022). Body weight and height were measured with the participants wearing light clothing and without shoes using a SECA model 206 digital scale and a portable stadiometer, respectively, according to the World Health Organization protocol. BMI [weight (kilograms)/height (square metres)] and WHR were calculated in relation to absolute values. The cut-off points in relation to overweight/obesity for BMI and WHR were calculated based on the medians, taking the 50th percentile as the score below which 50% of the scores in the distribution are found (Ialongo 2019).

Muscular strength

Isometric handgrip strength (kilograms) was measured with a Baseline brand hydraulic handgrip dynamometer (Baseline® Modelo LiTE®, Fabrication Enterprises, Inc., New York, NY, USA), according to the protocol of the American College of Sports Medicine (2013). The participant was tested in a standing position with the hand dynamometer placed parallel to the side of the body at waist level. The forearm should be level with the thigh. The subject can flex the arm slightly. Each participant made three attempts with each limb with a 1-min pause between attempts, considering the average of both as the final value (Tejero-Gonzalez *et al.* 2013; Farías-Valenzuela *et al.* 2022), carried out by the same evaluator in both opportunities. Prior to the application of the protocol, the evaluator carried out a test by providing a rubber ball to the participant (first attempt), to ensure that the evaluated person understood the instructions of the test (second and third attempts). Relative handgrip strength was calculated by dividing the absolute strength value by the subject's body mass [strength (kilograms)/weight (kilograms)] (Peterson *et al.* 2018). The asymmetries in handgrip strength were calculated according to the following formula: (stronger limb − weakest limb)/ stronger limb × 100 (Bishop *et al*. 2018).

To estimate low limb explosive strength, the countermovement vertical jump test (CMJ) was applied, which was assessed using a DM Jump® platform, recording height in centimetres. The participants started from the bipedal position with their hands on their hips and were asked to perform a flex extension of their knees to an angle of 90° to consecutively and without pause perform a maximum vertical jump without removing their hands from their hips (Villa & Garcia-Lopez 2005). Prior to the application of the test, the evaluator performed a demonstration and allowed the subjects to make two attempts to familiarise themselves with the movement. Then, the participants made two attempts and the average height (centimetres) reached in both was considered.

Statistical analysis

The Kolmogorov–Smirnov test was performed to assess the normality distribution of the data and the Levene test was performed for the analysis of homogeneity of variances. For continuous variables, mean and SD were presented, and for categorical variables, frequency and percentage were presented. Variables were presented as median and interquartile range (25th and 75th percentiles).

For the comparison of variables by age range, the analysis of covariance (parametric data), Kruskal–Wallis and chi-square tests (non-parametric data) were used. We calculated the adjusted residuals (z) and their associated P-values to detect positive ($z > 1.96$) and significant ($P < 0.05$) relationships among the variables analysed. The Bonferroni *post hoc* test was performed to determine where the differences between groups were.

The cut-off points of isometric handgrip and low limb explosive strength values for the prevention of overweight/obesity in people with IDs were identified using the receiver operating characteristic (ROC) curves. The total area under the ROC curve was identified between absolute and relative handgrip strength and CMJ with anthropometric measures of cardiometabolic risk (BMI and WHR) related to overweight/obesity. Sensitivity and specificity were then calculated, as well as cut-off points for absolute and relative handgrip and CMJ for the prevention of overweight and obesity in people with IDs. Participants in the underweight category according to BMI and WHR were excluded from the ROC curve. A 95% confidence interval (95% CI) and a significance of $P < 0.05$ were considered.

The cut-off points found for the strength categories were used to create new dichotomous variables (below and above the cut-off point). These variables were then considered as independent variables in logistic regression models, to quantify the effect that the strength categories below the cut-off point have on the risk of overweight and obesity (BMI and WHR). Models were made separated by age group and strength indicator (average absolute handgrip strength, average relative handgrip strength and average CMJ) adjusted by sex. The effects of the regression models were evaluated by odds ratio (OR) and their 95% CI. All results were analysed using SPSS software version 26 (SPSS Inc., IBM Corp., Armonk, NY, USA).

Results

Of the total 131 people with IDs who participated in this study, a 67.2% corresponded to male among children, adolescents and adults, with a mean age of 15.6 (SD: 7.2). Significant differences ($P < 0.05$) were found between age categories for body BMI and WHR, independent of sex. In the categories of overweight/obesity, significant differences were found by age category for BMI, but not for WHR (Table 1).

In the adjusted sex comparison of strength test results by age categories, significant differences were observed for levels of absolute and relative handgrip strength and CMJ ($P < 0.05$) (Table 2).

Tables 3 and 4 show the results of the ROC curve analysis, establishing the cut-off points for absolute strength (kilograms), relative strength and CMJ (centimetres) in relation to BMI and WHR and according to age categories. Correlation was made, but the results are not presented because it is not the main objective of the paper (data not presented). The area under the curve (AUC) indicates the best values for each age category (children, adolescents and adults). For the AUC analysis, 0.5 is generally considered a non-discriminatory test (incapable of differentiating between clinical and non-clinical individuals), an AUC of 0.7–0.8 to be acceptable and

Table 1 Descriptive analysis [*n* (%) or mean (standard deviation)] of indicators of overweight/obesity by age category

Variable	Total (*n* = 131)	Children (*n* = 43)	Adolescents (*n* = 39)	Adults (*n* = 49)	*P*	*F*	gl
Age (years) – average (SD)	15.6 (7.2)	8.2 (2.1)[d]	14.1 (1.5)[d]	23.2 (5.2)[d]	<0.001*		
Sex – *n* (%)							
Female	43 (32.8)	12 (27.9)	12 (30.8)	19 (38.8)			
Male	88 (67.2)	31 (72.1)	27 (69.2)	30 (61.2)			
Anthropometry – mean (SD)							
Body weight (kg)	56.3 (23.7)	35.3 (15.7)[e]	63.6 (21.4)	69.2 (18.2)	0.363†	0.83	
Height (m)	1.51 (0.1)	1.33 (0.1)[e]	1.61 (0.1)	1.58 (0.1)	0.204†	1.62	
BMI (kg/m^2)	23.9 (7.8)	18.8 (5.8)[e]	24.4 (6.4)	27.8 (8.0)	0.006†	7.81	
Neck perimeter (cm)	34.6 (5.8)	30.0 (3.6)[e]	35.4 (3.9)[d]	38.0 (6.0)[e]	0.151†	2.08	
Submandibular perimeter (mm)	8.5 (3.8)	8.0 (3.9)	8.5 (3.7)	8.9 (4.0)	0.571*		
Abdominal perimeter (cm)	77.8 (17.3)	66.1 (13.6)[e]	79.0 (16.2)	87.1 (15.1)	0.092†	2.88	
Calf perimeter (cm)	32.3 (6.0)	27.9 (5.4)[e]	33.7 (5.9)	34.9 (4.5)	0.081†	3.08	
Categories according to BMI – *n* (%)				0.55 (0.1)‡	<0.001‡		2
Eutrophic	70 (53)	32 (74.4)‡	20 (51.3)	18 (36.7)			
Overweight/obesity	61 (47)	11 (25.6)‡	19 (48.7)	31 (63.3)			
Categories according to WHR – *n* (%)					0.057‡		2
Eutrophic	63 (47.7)	25 (58.1)	21 (53.8)	17 (34.7)			
Overweight/obesity	68 (52.3)	18 (41.9)	18 (46.2)	32 (65.3)			

*Kruskal–Wallis significance value for independent samples.
†One-way analysis of covariance significance value for independent samples adjusted by sex.
‡Chi-square test significance value.
[d]$P < 0.05$: comparison of children–adolescents.
[e]$P < 0.05$: comparison of children–adults.
SD, standard deviation; BMI, body mass index; WHR, waist-to-height ratio.

Table 2 Descriptive analysis [*n* (%) or mean (standard deviation)] of isometric handgrip strength and low limb explosive strength tests according to age categories

Variables	Total	Children (*n* = 43)	Adolescents (*n* = 39)	Adults (*n* = 49)	*P*	*F*
Average absolute handgrip strength (kg)						
Average (SD)	19.4 (12.5)	8.7 (5.5)	25.9 (12.9)	21.2 (11.1)	<0.001*	
Median (P25–P75)	16.7 (9.9–28.2)	9.2 (2.8–13.0)	27.0 (15.2–35.7)	20.0 (12.0–29.0)		
Average relative handgrip strength						
Average (SD)	0.32 (0.19)	0.29 (0.16)	0.32 (0.18)	0.35 (0.21)	0.02†	10.50
Median (P25–P75)	0.30 (0.19–0.45)	0.29 (0.18–0.39)	0.32 (0.17–0.44)	0.28 (0.20–0.48)		
CMJ average (cm)						
Average (SD)	11.5 (7.3)	8.6 (5.5)	15.2 (8.1)	10.5 (6.5)	<0.001†	13.76
Median (P25–P75)	10.6 (6.1–17.4)	9.1 (3.6–12.5)	13.5 (8.5–21.7)	9.4 (6.1–17.4)		

*Kruskal–Wallis significance value for independent samples.
†Analysis of covariance significance value for independent samples adjusted by sex.
[d]$P < 0.05$: comparison of children–adolescents.
[e]$P < 0.05$: comparison of children–adults.
SD, standard deviation.

Table 3 Isometric handgrip and low limb explosive strength cut-off points according to age categories in relation to body mass index

		AUC	95% CI	*P*	Sensit. (%)	Specif. (%)	Cut-off
Absolute strength average	Children	0.722	0.528–0.916	0.750	0.750	0.500	8.8
	Adolescents	0.577	0.363–0.791	0.477	0.765	0.615	19.1
	Adults	0.511	0.294–0.727	0.922	0.478	0.600	21.3
Relative strength average	Children	0.451	0.188–0.714	0.697	0.625	0.611	0.24
	Adolescents	0.367	0.160–0.573	0.217	0.529	0.615	0.29
	Adults	0.478	0.284–0.672	0.845	0.478	0.600	0.28
CMJ average	Children	0.507	0.279–0.735	0.956	0.500	0.556	9.7
	Adolescents	0.321	0.120–0.523	0.098	0.353	0.615	14.2
	Adults	0.376	0.148–0.604	0.264	0.522	0.700	8.9

AUC, area under the curve; 95% CI, 95% confidence interval; Sensit., sensitivity; Specif., specificity; CMJ, countermovement jump.

Table 4 Isometric handgrip and low limb explosive strength cut-off points according to age categories in relation to waist-to-height ratio

		AUC	95% CI	*P*	Sensit. (%)	Specif. (%)	Cut-off
Absolute strength average	Children	0.728	0.515–0.941	0.048	0.692	0.462	8.8
	Adolescents	0.427	0.213–0.640	0.494	0.667	0.533	22.7
	Adults	0.492	0.297–0.704	0.939	0.455	0.636	21.3
Relative strength average	Children	0.385	0.165–0.604	0.317	0.615	0.615	0.24
	Adolescents	0.356	0.155–0.556	0.178	0.267	0.400	0.39
	Adults	0.579	0.386–0.771	0.468	0.545	0.636	0.26
CMJ average	Children	0.503	0.275–0.731	0.980	0.538	0.538	9.7
	Adolescents	0.222	0.057–0.388	0.010	0.267	0.533	17.1
	Adults	0.349	0.132–0.566	0.163	0.318	0.545	12.9

AUC, area under the curve; 95% CI, 95% confidence interval; Sensit., sensitivity; Specif., specificity; CMJ, countermovement jump.

an AUC of 0.9 to be excellent (Hosmer *et al.* 2013). Regarding sensitivity, the recommended guidelines for selected cut-off points were used as a reference, considering either 50% or 90% of sensitivity (Sugarman & Axelrod 2015). In general, the cut-off points to determine overweight/obesity established for absolute strength, relative strength and CMJ showed similar values established according to BMI and WHR. In the analysis by age categories, the lowest cut-off points for absolute strength and relative strength according to BMI and WHR were observed in children, with values of 8.8 kg and 0.24, respectively. Only in the analysis according to BMI, adults demonstrated the lowest cut-off point of 8.9 cm for CMJ. Adolescents demonstrated the highest cut-off values of 0.29 and 14.2 for relative strength and CMJ according to BMI, respectively, and 22.7, 0.39 and 17.1 for absolute strength, relative strength and CMJ in relation to WHR, respectively. In the case of absolute strength, adults showed the highest value of 21.3 kg only according to BMI. Tables 3 and 4 also show the CI, sensitivity and specificity to determine overweight/obesity using isometric handgrip and low limb explosive strength values. In general, sensitivity was moderately higher for absolute and relative strength compared with CMJ. Higher specificity was observed in the analysis in relation to BMI than WHR, in all categories. The highest sensitivity for absolute strength in relation to BMI was demonstrated in the group of children [75%; 95% CI (52.8–91.6%)] and adolescents [76.5%; 95% CI (52.8–91.6%)]. The greatest specificity was observed in the adult group (63.6%) for absolute strength (95% CI 29.7–70.4%) and relative strength (95% CI 38.6–77.1%) according to WHR.

Tables 5 and 6 show the univariate logistic regression for each strength type from the cut-off points in BMI and WHR, respectively. Only in children (OR = 2.72, 95% CI 1.19–6.20) and adolescents (OR = 2.31, 95% CI 1.12–4.74), the average relative handgrip strength and average absolute handgrip strength had significant association on the classification of BMI and WHR.

Discussion

The aim of this study was to establish cut-off points for isometric handgrip and low limb explosive strength that identify overweight/obesity by age categories in children, adolescents and adults with IDs. The main findings show higher levels of absolute strength and CMJ in the adolescent group compared with children and adults, as well as higher cut-off points for relative strength and CMJ for overweight/obesity. For absolute strength, the highest cut-off point was established in the adult group according to BMI. We found distinct associations between cut-off points with BMI and WHR by age groups.

The BMI considered in this study has proven to be a sufficient indicator to determine obesity in adults with IDs (Gawlik *et al.* 2018), in addition to demonstrating a significant correlation with the percentage of fat in young people with Down syndrome (Gómez-Campos *et al.* 2021). The main

Table 5 Logistic regression model of the association between cut-off value of absolute strength, relative strength and countermovement jump of children, adolescents and adults that indicates obesity according to body mass index

	Children		Adolescents		Adults	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Average absolute handgrip strength (kg)	0.509 (0.191–1.35)	0.177	0.958 (0.483–1.90)	0.903	1.13 (0.574–2.25)	0.711
Average relative handgrip strength	0.351 (0.156–0.387)	0.011*	0.634 (0.313–1.28)	0.207	0.594 (0.292–1.21)	0.152
CMJ average (cm)	0.775 (0.378–1.58)	0.484	0.454 (0.226–0.924)	0.029*	0.837 (0.402–1.74)	0.634

*$P < 0.05$.
OR, odds ratio; 95% CI, 95% confidence interval; CMJ, countermovement jump.
Reference: obesity (1) and under cut-off point (0), adjusted by sex.

Table 6 Logistic regression model of the association between cut-off value of absolute strength, relative strength and countermovement jump of children, adolescents and adults that indicates obesity according to waist-to-height ratio

	Children		Adolescents		Adults	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Average absolute handgrip strength (kg)	0.995 (0.391–2.53)	0.991	0.413 (0.204–0.834)	0.014*	0.506 (0.253–1.01)	0.054
Average relative handgrip strength	0.471 (0.211–1.05)	0.066	0.690 (0.339–1.40)	0.304	0.642 (0.314–1.31)	0.223
CMJ average (cm)	0.632 (0.307–1.30)	0.213	0.586 (0.293–1.17)	0.131	0.563 (0.267–1.18)	0.132

*$P < 0.05$.
OR, odds ratio; 95% CI, 95% confidence interval; CMJ, countermovement jump.
Reference: obesity (1) and under cut-off point (0), adjusted by sex.

results show significant differences between age categories, where adults showed the highest percentage of high BMI (63.3%), indicating a higher prevalence of overweight/obesity compared with 48% and 25% in adolescents and children, respectively. Our results are in line with other studies conducted in older adults with IDs over 40 years of age, where 69% of the participants demonstrated levels of overweight/obesity, associated with a higher risk of cardiometabolic disease (Ryan *et al.* 2021). Our results are even higher than those found in a study conducted in adults with IDs in Latin America, where the prevalence of overweight/obesity was 40% (Foley *et al.* 2017), considering that its participants were physically active athletes compared with the most sedentary individuals of this study.

In relation to strength levels, studies have confirmed that people with IDs have less muscle mass and strength, which is a determining factor for the decrease in functional capacities (Merchán-Baeza *et al.* 2020); however, no differences by age groups have been established. In the present study, adolescents demonstrated higher levels of isometric handgrip and low limb explosive strength compared with children and adults. In general, in children with IDs, results below the reference values are observed for muscular strength, resistance and cardiorespiratory fitness tests (Wouters *et al.* 2020), in addition to worse results in low limb explosive strength and handgrip strength in comparison with their peers without disabilities (Hartman *et al.* 2015). In the case of adults with IDs, as in our study, mean isometric strength has been estimated to be lower than in young people and similar to older adults (Heffernan *et al.* 2009). Previous results obtained in CMJ in adolescents have shown an increase from 5% to 29% in adolescents aged 12 and 17, respectively, suggesting that the values obtained in this test increase with age (Hackett *et al.* 2021). However, this contrasts with our results, where CMJ results decrease as age increases, suggesting a physical and functional deterioration during adulthood in people with IDs, where levels of muscle mass and physical performance are very high worsened, similar or lower than those of older adults without IDs with sarcopenia, according to bioelectrical impedance analysis and dual X-ray absorptiometry measurements (Coelho-Junior *et al.* 2019). In general, the results show that in people with IDs, the peak of strength development occurs in the adolescent stage and then declines in the adult stage (18–45 years), a condition that occurs later in people without disabilities, occurring an abrupt deterioration around 41 and 66 years of age in women and men, respectively (Haynes *et al.* 2020). This could be associated with the anticipated physical and functional deterioration of adults with IDs, which occurs between the ages of 40 and 50 years due to poor physical condition and health problems associated with a higher risk of suffering from chronic diseases (Peirats & Burgos 2010; Oviedo *et al.* 2020).

In the analysis by age categories, there are no previous studies that establish a cut-off point for isometric handgrip and low limb explosive strength in people with IDs. The lowest cut-off points for overweight/obesity by age categories were established in children for absolute strength (8.8 kg) and relative strength (0.24), results that could be explained by a lower weight and a protective effect associated with younger age with respect to the other groups. These results in children with IDs are lower than the cut-off points for relative strength to identify cardiometabolic risk in Chilean children, where the values were 0.33 in boys and 0.40 in girls (López-Gil *et al.* 2021).

The highest cut-off points according to BMI for relative strength and CMJ in the adolescent group were set at 0.29 and 14.2 cm, respectively, and for absolute strength at 21.3 kg in the adult group. These results suggest that both groups will need higher levels of strength to have a protective effect against overweight/obesity compared with children, which is associated with a high prevalence of overweight (28–71%) and obesity (17–43%) in adults with IDs that increases with age (Ranjan *et al.* 2018), leading to an extremely high prevalence of multimorbidity in adults with IDs throughout the adult life course (Kinnear *et al.* 2018). Previous studies have shown similar results to our research, with a relative strength cut-off point of 0.25 associated with a reduced odds of metabolic syndrome in men under 50 years, independent of BMI (Sénéchal *et al.* 2014). However, other studies have stablished higher relative strength cut-off points for intermediate risk of metabolic syndrome in adults from 18 to 30 years old, showing values of <0.46 in male and ≤0.43 in female (Garcia-Hermoso *et al.* 2020). These results are higher compared with our findings, where the strength cut-off points for overweight/obesity in the adult group were stablished at 0.28 and 0.26 for relative strength related to BMI and WHR, respectively, suggesting that levels of isometric handgrip and low limb explosive strength to obtain a protective effect against obesity in people with IDs are lower and less demanding compared with adults without disability.

It is well documented that individuals with IDs are less active and have lower strength than peers without IDs (Alcántara-Cordero *et al.* 2020; Wouters *et al.* 2020; Simón-Siles *et al.* 2022). However, there are few published efforts to know cut-off points for isometric handgrip and low limb explosive strength in this population segment. The research in this area is growing and an evaluation of this work is fundamental to identifying effective strategies for increasing physical fitness level and health outcomes among individuals with IDs. Thus, our findings expand previous evidence for different age groups, suggesting a cut-off point according to BMI and WHR, which are within the recommendations for the prevention of overweight/obesity and other related health problems. The different research instruments and parameters used to classify the strength, beyond the cut-offs, make it difficult to compare the results with those of other studies (Virtuoso Júnior *et al.* 2012). Finally, there are many challenges to conducting large-scale interventions in youth with IDs, so researchers are encouraged to develop multi-site collaborative projects to increase sample size, strengthen research design and improve generalisability of findings.

Some limitations of this study include its cross-sectional design, whose database is limited to people with IDs and their characteristics, which could affect the CMJ test results, although there are studies that report its use as associations with other manifestations of force still requires validation. Also, associated syndromes were not considered and so that the results cannot be extended to other populations. The work presented here had low number of participants per age group, therefore limiting the generalisability to results for each age group. Moreover, it is likely that a sex difference will appear during puberty on physical fitness data and the reference values that were used were not sex specific. Also, strength levels necessary for daily activities such as functional activities, transportation and work, should point towards the design of strength training strategies from school contexts. Nevertheless, the strengths of the study include that the analysis was carried out by age categories, which is innovative and allows the establishment of cut-off points to identify the needs of each age group in relation to strength and the prevention of overweight/obesity. This study expands the existing literature by reporting the cut-off points for isometric handgrip and low limb explosive strength in relation to indicators of overweight/obesity in people with IDs and represents the first study of this kind in Chile. Thus, the degree to which the results are generalisable to other regions is not known.

Conclusions

In the present study, adolescents presented higher cut-off points for absolute strength, relative strength and CMJ for overweight/obesity according to BMI and WHR in comparison with children and adults. Only in relation to BMI, the highest cut-off point for absolute strength was stablished in the adult group. Different associations between cut-off points with BMI and WHR were found by age group. This study suggests that isometric handgrip and low limb explosive strength levels should be adjusted by age categories, making essential the implementation of physical exercise programmes that can contribute to the improvement of strength levels throughout the entire vital cycle for the prevention of overweight/obesity in people with IDs.

Author Contributions

P.F.-H. and C.F.-V. conceived, designed and helped write and revise the manuscript. P.F.-H., C.F.-V. and P.V.-M. were responsible for coordinating the study, contributed to the intellectual content and revised the manuscript. P.F.-H., C.F.-V., G.F., S.E.-L., S.A.-A. and P.V.-M. interpreted the data and helped write and revise the manuscript. All authors contributed to the study design, critically reviewed the manuscript and approved the final version.

Acknowledgements

Funding for open access charge: Universidad de Granada/CBUA. The authors would like to thank the staff and participants of each of the participating sites who made substantial contributions to this study.

Source of funding

No external funding was received for the research reported in the paper.

Conflict of interest

The authors declare that they have no conflicts of interest.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available because of privacy or ethical restrictions.

References

Alcántara-Cordero F. J., Gómez-Píriz P. T., Sánchez-López A. M. & Cabeza-Ruiz R. (2020) Feasibility and reliability of a physical fitness tests battery for adults with intellectual disabilities: the SAMU DIS-FIT battery. *Disability and Health Journal* **13**, 100886.

American College of Sports Medicine (ed.) (2013) *ACSM's Health-Related Physical Fitness Assessment Manual*. Lippincott Williams & Wilkins.(Ed.)

Bertapelli F., Pitetti K., Agiovlasitis S. & Guerra-Junior G. (2016) Overweight and obesity in children and adolescents with Down syndrome-prevalence, determinants, consequences, and interventions: a literature review. *Research in Developmental Disabilities* **57**, 181–92.

Bishop C., Read P., Lake J., Chavda S. & Turner A. (2018) Interlimb asymmetries: understanding how to calculate differences from bilateral and unilateral tests. *Strength and Conditioning Journal* **40**, 1–6.

Borland R. L., Hu N., Tonge B., Einfeld S. & Gray K. M. (2020) Participation in sport and physical activity in adults with intellectual disabilities. *Journal of intellectual disability research: JIDR* **64**, 908–22.

Carmeli E., Imam B. & Merrick J. (2012) The relationship of pre-sarcopenia (low muscle mass) and sarcopenia (loss of muscle strength) with functional decline in individuals with intellectual disability (ID). *Archives of Gerontology and Geriatrics* **55**, 181–5.

Coelho-Junior H. J., Villani E. R., Calvani R., Carfì A., Picca A., Landi F. *et al.* (2019) Sarcopenia-related parameters in adults with Down syndrome: a cross-sectional exploratory study. *Experimental Gerontology* **119**, 93–9.

De Lima T. R., Martins P. C., Guerra P. H. & Santos Silva D. A. (2021) Muscular strength and cardiovascular risk factors in adults: a systematic review. *The Physician and Sportsmedicine* **49**, 18–30.

Diets I. J., van der Donk R., Baltrunaite K., Waanders E., Reijnders M. R. F., Dingemans A. J. M. *et al.* (2019) De novo and inherited pathogenic variants in KDM3B cause intellectual disability, short stature, and facial dysmorphism. *The American Journal of Human Genetics* **104**, 758–66.

Doody C. M. & Doody O. (2012) Health promotion for people with intellectual disability and obesity. *British Journal of Nursing* **21**, 460–5.

Engin A. (2017) The definition and prevalence of obesity and metabolic syndrome. *Obesity and lipotoxicity* **960**, 1–17.

Farías-Valenzuela C., Arenas-Sánchez G., Cofré-Bolados C., Espinoza-Salinas A., Alvarez-Arangua S. & Espoz-Lazo S. (2019) Pruebas dinamométricas y desempeño funcional en adolescentes con discapacidad intelectual moderada. *Journal of Sport and Health Research* **11**, 229–38.

Farías-Valenzuela C., Ferrero-Hernández P., Ferrari G., Espoz-Lazo S., Castillo-Paredes A., Álvarez-Arangua S. *et al.* (2022) Reference values of absolute and relative handgrip strength in Chilean schoolchildren with intellectual disabilities. *Children* **9**, 1912.

Foley J. T., Lloyd M., Turner L. & Temple V. A. (2017) Body mass index and waist circumference of Latin American adult athletes with intellectual disability. *Salud Pública de México* **59**, 416–22.

García-Hermoso A., Cavero-Redondo I., Ramírez-Vélez R., Ruiz J. R., Ortega F. B., Lee D. C. *et al.* (2018) Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. *Archives of Physical Medicine and Rehabilitation* **99**, 2100–13.e2105.

Garcia-Hermoso A., Tordecilla-Sanders A., Correa-Bautista J. E., Peterson M. D., Izquierdo M., Quino-Ávila A. C. *et al.* (2020) Muscle strength cut-offs for the detection of metabolic syndrome in a nonrepresentative sample of collegiate students from Colombia. *Journal of Sport and Health Science* **9**, 283–90.

Gawlik K., Zwierzchowska A. & Celebańska D. (2018) Impact of physical activity on obesity and lipid profile of adults with intellectual disability. *Journal of Applied Research in Intellectual Disabilities* **31**, 308–11.

Gómez-Campos R., Vidal-Espinoza R., Castelli-Correia de Campos L. F., Marques de Moraes A., Lázari E., Cossio Bolaños W. *et al.* (2021) Estimation of fat mass by anthropometric indicators in young people with Down syndrome. *Nutrición Hospitalaria* **38**, 1040–6.

Hackett D. A., He W., Orr R. & Sanders R. (2021) Effects of age and sex on field-based measures of muscle strength and power of the upper and lower body in adolescents. *Journal of Sports Sciences* **39**, 955–60.

Hartman E., Smith J., Westendorp M. & Visscher C. (2015) Development of physical fitness in children with intellectual disabilities. *Journal of Intellectual Disability Research* **59**, 439–49.

Hassani A., Kotzamanidou M. C., Tsimaras V., Lazaridis S., Kotzamanidis C. & Patikas D. (2014) Differences in counter-movement jump between boys with and without intellectual disability. *Research in Developmental Disabilities* **35**, 1433–8.

Haynes E. M. K., Neubauer N. A., Cornett K. M. D., O'Connor B. P., Jones G. R. & Jakobi J. M. (2020) Age and sex-related decline of muscle strength across the adult lifespan: a scoping review of aggregated data. *Applied Physiology, Nutrition, and Metabolism* **45**, 1185–96.

Heffernan K. S., Sosnoff J. J., Ofori E., Jae S. Y., Baynard T., Collier S. R. *et al.* (2009) Complexity of force output during static exercise in individuals with Down syndrome. *Journal of Applied Physiology* **106**, 1227–33.

Hosmer D. W., Jr., Lemeshow S. & Sturdivant R. X. (2013) *Applied Logistic Regression*, vol. **398**. John Wiley & Sons.

Hsieh K., Rimmer J. H. & Heller T. (2014) Obesity and associated factors in adults with intellectual disability. *Journal of Intellectual Disability Research* **58**, 851–63.

Ialongo C. (2019) Confidence interval for quantiles and percentiles. *Biochemia medica* **29**, 5–17.

Jabłonowska-Lietz B., Wrzosek M., Włodarczyk M. & Nowicka G. (2017) New indexes of body fat distribution, visceral adiposity index, body adiposity index, waist-to-height ratio, and metabolic disturbances in the obese. *Kardiologia Polska* **75**, 1185–91.

Jacinto M., Oliveira R., Brito J. P., Martins A. D., Matos R. & Ferreira J. P. (2021) Prescription and effects of strength training in individuals with intellectual disability – a systematic review. *Sports* **9**, 125.

Kasagi K. (2021) Evaluating obesity index among children with developmental disorders. *Open Journal of Nursing* **11**, 57–64.

Kelly R., Hatzikiriakidis K. & Kuswara K. (2022) Inequities in obesity: Indigenous, culturally and linguistically diverse, and disability perspectives. *Public Health Research and Practice* **32**, 3232225.

Kinnear D., Morrison J., Allan L., Henderson A., Smiley E. & Cooper S. A. (2018) Prevalence of physical conditions and multimorbidity in a cohort of adults with intellectual disabilities with and without Down syndrome: cross-sectional study. *BMJ Open* **8**, e018292.

Krause S., Ware R., McPherson L., Lennox N. & O'Callaghan M. (2016) Obesity in adolescents with intellectual disability: prevalence and associated characteristics. *Obesity Research and Clinical Practice* **10**, 520–30.

López-Gil J. F., Weisstaub G., Ramírez-Vélez R. & García-Hermoso A. (2021) Handgrip strength cut-off points for early detection of cardiometabolic risk in Chilean children. *European Journal of Pediatrics* **180**, 3483–9.

Martínez-Espinosa R. M., Molina Vila M. D. & Reig García-Galbis M. (2020) Evidences from clinical trials in Down syndrome: diet, exercise and body composition. *International Journal of Environmental Research and Public Health* **17**, 4294.

Merchán-Baeza J. A., Pérez-Cruzado D., González-Sánchez M. & Cuesta-Vargas A. (2020) Development of a new index of strength in adults with intellectual and developmental disabilities. *Disability and Rehabilitation* **42**, 1918–22.

Obrusnikova I., Firkin C. J., Cavalier A. R. & Suminski R. R. (2022) Effects of resistance training interventions on muscular strength in adults with intellectual disability: a systematic review and meta-analysis. *Disability and Rehabilitation* **44**, 4549–62.

Oviedo G. R., Javierre C., Font-Farré M., Tamulevicius N., Carbó-Carreté M., Figueroa A. *et al.* (2020) Intellectual disability, exercise and aging: the IDEA study: study protocol for a randomized controlled trial. *BMC Public Health* **20**, 1266.

Peirats E. & Burgos E. (2010) Discapacidad intelectual y envejecimiento: Un problema social del siglo XXI. *Colección FEAPS* **12**.

Peterson M. D., Gordon P. M., Smeding S. & Visich P. (2018) Grip strength is associated with longitudinal health maintenance and improvement in adolescents. *The Journal of Pediatrics* **202**, 226–30.

Ramírez V. & Rosas R. (2007) Estandarización del WISC-III en Chile: Descripción del Test, Estructura Factorial y Consistencia Interna de las Escalas. *Psykhe* **16**, 91–109.

Ranjan S., Nasser J. A. & Fisher K. (2018) Prevalence and potential factors associated with overweight and obesity status in adults with intellectual developmental disorders. *Journal of Applied Research in Intellectual Disabilities* **31**, 29–38.

Real de Asua D., Parra P., Costa R., Moldenhauer F. & Suarez C. (2014) A cross-sectional study of the phenotypes of obesity and insulin resistance in adults with down syndrome. *Diabetes and Metabolism Journal* **38**, 464–71.

Rosas R., Tenorio M., Pizarro M., Cumsille P., Bosch A., Arancibia S. *et al.* (2014) Estandarización de la Escala Wechsler de Inteligencia Para Adultos: Cuarta Edición en Chile. *Psykhe* **23**, 1–18.

Ryan J., McCallion P., McCarron M., Luus R. & Burke E. A. (2021) Overweight/obesity and chronic health conditions in older people with intellectual disability in Ireland. *Journal of Intellectual Disability Research* **65**, 1097–109.

Segal M., Eliasziw M., Phillips S., Bandini L., Curtin C., Kral T. V. E. *et al.* (2016) Intellectual disability is associated with increased risk for obesity in a nationally representative sample of U.S. children. *Disability and Health Journal* **9**, 392–8.

Sénéchal M., McGavock J. M., Church T. S., Lee D. C., Earnest C. P., Sui X. *et al.* (2014) Cut points of muscle strength associated with metabolic syndrome in men. *Medicine and Science in Sports and Exercise* **46**, 1475–81.

Silva V., Campos C., Sá A., Cavadas M., Pinto J., Simões P. *et al.* (2017) Wii-based exercise program to improve physical fitness, motor proficiency and functional mobility in adults with Down syndrome. *Journal of Intellectual Disability Research* **61**, 755–65.

Simón-Siles S., Font-Farré M., Guerra-Balic M., Nishishinya-Aquino M. B. & Oviedo G. R. (2022) Effects of exercise on fitness in adults with intellectual disability: a protocol of an overview of systematic reviews. *BMJ Open* **12**, e058053.

Smail K. M. & Horvat M. (2006) Relationship of muscular strength on work performance in high school students with mental retardation. *Education and Training in Developmental Disabilities* **414**, 410–9.

Soheilipour F., Hatami M., Salehiniya H. & Alaei M. (2022) Indicators of obesity and cardio-metabolic risks: important consideration in adults and children. *Current Diabetes Reviews* **18**, e160721194839.

Sugarman M. A. & Axelrod B. N. (2015) Embedded measures of performance validity using verbal fluency tests in a clinical sample. *Applied Neuropsychology. Adult* **22**, 141–6.

Sugimoto D., Bowen S. L., Meehan W. P., 3rd & Stracciolini A. (2016) Effects of neuromuscular training on children and young adults with Down syndrome: systematic review and meta-analysis. *Research in Developmental Disabilities* **55**, 197–206.

Tejero-Gonzalez C. M., Martinez-Gomez D., Bayon-Serna J., Izquierdo-Gomez R., Castro-Piñero J. & Veiga O. L. (2013) Reliability of the ALPHA health-related fitness test battery in adolescents with Down syndrome. *The Journal of Strength and Conditioning Research* **27**, 3221–4.

Villa J. G. & Garcia-Lopez J. (2005) Tests de salto vertical (I): Aspectos funcionales. *Revista Digital: Rendimiento Deportivo. com* **6**, 1–14.

Virtuoso Júnior J. S., Tribess S., Paulo T. R. S. D., Martins C. A. & Romo-Perez V. (2012) Physical activity as an indicator of predictive functional disability in elderly. *Revista Latino-Americana de Enfermagem* **20**, 259–65.

Wouters M., Evenhuis H. M. & Hilgenkamp T. I. (2020) Physical fitness of children and adolescents with moderate to severe intellectual disabilities. *Disability and Rehabilitation* **42**, 2542–52.

Wyszyńska J., Podgórska-Bednarz J., Dereń K., Baran J., Czenczek-Lewandowska E., Leszczak J. *et al.* (2020) Associations between adiposity indicators and hypertension among children and adolescents with intellectual disability – a case-control study. *Journal of applied research in intellectual disabilities: JARID* **33**, 1133–40.

Zghal F., Borji R., Colson S. S., Sahli S. & Rebai H. (2019) Neuromuscular characteristics in trained vs. sedentary male adults with intellectual disability. *Journal of Intellectual Disability Research* **63**, 1334–45.

Accepted 9 July 2023