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CARDIOMETABOLIC PROFILE AND VO_2MAX PREDICTORS: AN INTEGRATIVE STUDY COMPARING ANTHROPOMETRIC AND PHYSIOLOGICAL PARAMETERS IN FEMALE ADOLESCENTS WITH AND WITHOUT INTELLECTUAL DISABILITY

KARDIOMETABOLIČKI PROFIL I PREDIKTORI VO_2max: INTEGRATIVNA STUDIJA POREĐENJA ANTROPOMETRIJSKIH I FIZIOLOŠKIH PARAMETARA KOD ADOLESCENTICA SA I BEZ INTELEKTUALNIH TEŠKOĆA

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ABSTRACT

Female adolescents with intellectual disability (ID) are at increased risk of adiposity and cardiometabolic disorders. However, the determinants of cardiorespiratory fitness (VO_2max) remain insufficiently documented in the Democratic Republic of the Congo. This study aimed to compare the anthropometric and physiological characteristics of female adolescents with and without ID and to identify the predictors of VO_2max using a multiple linear regression model. This analytical cross-sectional study included 252 female adolescents, comprising 129 with ID and 123 without ID. Anthropometric and physiological measurements included body weight, height, body mass index (BMI), heart rate (HR), respiratory rate (RR), systolic and diastolic blood pressure (SBP and DBP), and VO_2max.

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Group comparisons were performed using the independent Student's *t*-test. Pearson correlation and multiple linear regression analyses were conducted to identify the determinants of VO_2max. Female adolescents with ID had significantly higher body weight and BMI, lower height, and markedly lower VO_2max than those without ID (all $p < .001$). Multiple linear regression analysis showed that VO_2max was positively associated with respiratory rate ($\beta = 0.336$, $p < .001$) and heart rate ($\beta = 0.189$, $p = .002$), whereas BMI was negatively associated with VO_2max ($\beta = -0.123$, $p = .046$). The regression model explained approximately 28% of the variance in VO_2max (adjusted $R^2 = 0.28$). Age and the combined influence of cardiovascular and ventilatory parameters also appeared to contribute to cardiorespiratory fitness. Female adolescents with ID exhibited an unfavorable cardiometabolic profile characterized by increased adiposity and reduced cardiorespiratory fitness. Respiratory rate, heart rate, and BMI were significant independent predictors of VO_2max. These findings underscore the importance of multidimensional interventions, including adapted physical activity programs and regular cardiovascular monitoring, to improve the health and physical fitness of this vulnerable population.

Keywords: female adolescents; intellectual disability; anthropometric parameters; physiological parameters; cardiorespiratory fitness; VO_2max.

SAŽETAK

Adolescentice s intelektualnim teškoćama (IT) izložene su povećanom riziku od prekomjernog nakupljanja masnog tkiva i kardiometaboličkih poremećaja. Međutim, determinante kardiorespiratorne kondicije (VO_2max) još uvijek nisu dovoljno istražene u Demokratskoj Republici Kongo. Cilj ovog istraživanja bio je usporediti antropometrijske i fiziološke karakteristike adolescentica sa i bez IT te identificirati prediktore VO_2max primjenom modela multiple linearne regresije. U ovoj analitičkoj presječnoj studiji učestvovale su 252 adolescentice, od kojih 129 s IT i 123 bez IT. Antropometrijska i fiziološka mjerenja obuhvatala su tjelesnu masu, tjelesnu visinu, indeks tjelesne mase (BMI), srčanu frekvenciju (HR), frekvenciju disanja (RR), sistolički i dijastolički krvni pritisak (SBP i DBP) te VO_2max. Poređenje grupa provedeno je primjenom nezavisnog Studentovog *t*-testa. Za identifikaciju determinanti VO_2max provedene su Pearsonova korelacijska analiza i multipla linearna regresijska analiza.

Adolescentice s IT imale su statistički značajno veću tjelesnu masu i BMI, nižu tjelesnu visinu i izrazito niži VO_2max u odnosu na adolescentice bez IT (sve $p < .001$). Multipla linearna regresijska analiza pokazala je da je VO_2max bio pozitivno povezan s frekvencijom disanja ($\beta = 0.336$, $p < .001$) i srčanom frekvencijom ($\beta = 0.189$, $p = .002$), dok je BMI bio negativno povezan s VO_2max ($\beta = -0.123$, $p = .046$). Regresijski model objasnio je približno 28% varijanse VO_2max (prilagođeni $R^2 = .28$). Dob i zajednički uticaj kardiovaskularnih i ventilacijskih parametara također su se pokazali kao mogući faktori koji doprinose kardiorespiratornoj kondiciji. Adolescentice s IT imale su nepovoljan kardiometabolički profil, karakteriziran povećanim nakupljanjem masnog tkiva i smanjenom kardiorespiratornom kondicijom. Frekvencija disanja, srčana frekvencija i BMI bili su značajni nezavisni prediktori VO_2max.

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Ovi rezultati naglašavaju važnost multidimenzionalnih intervencija, uključujući prilagođene programe tjelesne aktivnosti i redovno praćenje kardiovaskularnog zdravlja, s ciljem unapređenja zdravlja i tjelesne kondicije ove vulnerabilne populacije.

Ključne riječi: adolescentice, intelektualne teškoće, antropometrijski parametri, fiziološki parametri, kardiorespiratorna kondicija, VO_2max.

INTRODUCTION

Intellectual disability (ID) is characterized by significant limitations in intellectual functioning and adaptive behavior and affects approximately 1-3% of adolescents worldwide (Zaliene et al., 2025). In sub-Saharan African countries, including the Democratic Republic of the Congo (DRC), limited attention has been given to the physical health of female adolescents with ID despite the increasing prevalence of childhood and adolescent adiposity in urban settings (Mukalay et al., 2021). In the DRC, female adolescents with ID are frequently exposed to socioeconomic, nutritional, and environmental constraints that restrict access to physical activity and sports participation, thereby increasing their risk of adiposity and cardiometabolic disorders (Mugisha et al., 2023).

These health challenges are particularly important during adolescence because pubertal development, bone maturation, and body composition may be adversely affected by excess body fat and poor cardiorespiratory fitness, especially among girls (Alghadir et al., 2022 ; Nolan et al., 2025). Maximal oxygen uptake (VO_2max), a key indicator of aerobic capacity and cardiovascular health, is widely used to assess physical fitness and predict the risk of chronic diseases. However, evidence regarding the determinants of VO_2max in female adolescents with ID in the Congolese context remains scarce, particularly concerning the combined influence of anthropometric characteristics (height, weight, and body mass index [BMI]) and physiological parameters, including heart rate, respiratory rate, and blood pressure.

Previous international studies have shown that VO_2max is influenced by both anthropometric and physiological factors, including BMI, height, heart rate, respiratory rate, and blood pressure (Jancinto et al., 2023; Conrad et al., 2022 ; Bar et al., 2023). Nevertheless, no study conducted in the DRC has investigated these associations using an integrative approach that combines comparative, correlational, and predictive analyses among female adolescents with ID. The present study was therefore designed to address this gap in the literature.

Specifically, this study aimed to compare the anthropometric and physiological characteristics of Congolese female adolescents with and without ID, to examine the relationships between these variables and VO_2max, and to identify the main predictors of cardiorespiratory fitness using a multiple linear regression model.

We hypothesized that female adolescents with ID would exhibit a less favorable anthropometric and physiological profile, characterized by higher BMI, shorter stature, and lower VO_2max than their peers without ID. We further hypothesized that VO_2max would be independently associated with key physiological variables, particularly respiratory rate and heart rate, as well as with BMI.

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MATERIAL AND METHODS

Study Design

This analytical cross-sectional study was conductes between November 2022 and Febuary 2023 to compare the anthropometric and physiological profile of female adolescents with and without intellectual disability (ID) in Kinshasa, Democratic Republic of the Congo (DRC).
The study design enabled comparisons between groups and the investigation of associations among anthropometric characteristics, physiological parameters, and cardiorespiratory fitness (VO_2max).

Population and sample

The study population consisted of female adolescents aged 12-17 years enrolled in seven schools in Kinshasa.
The final sample included 252 participants, divided into two groups:

- ID group: 129 female adolescents diagnosed with moderate intellectual disability according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). Participants were recruited from five special education schools: Bondeko Twendeleye Village, Sembola, Mawete, Kikesa, and Bon Départ.
- Non-ID group: 123 female adolescents without intellectual disability, recruited from two mainstream schools: Complexe Scolaire Les Chérubins and Collège Frère Emmanuel Stablum.

Participants were recruited using a convenience sampling strategy.

Inclusion Criteria

Participants were included if they:

- Were aged 12–17 years;
- Had a confirmed diagnosis of moderate ID (for the ID group), established by a psychologist and a neuropsychiatrist;
- Were medically able to participate in the physical assessments.
- Provided written informed consent signed by parents or legal guardians;
- Were present on the assessment days.

Exclusion Criteria

Participants were excluded if they:

- Had chronic diseases such as cardiovascular disease or severe asthma;
- Were taking medications that could influence heart rate or blood pressure;
- Were unable to complete the physical assessments.

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Ethical Considerations

The study protocol was approved by the National Ethics Committee (No. 404/CNES/PMMF/2022; October 30, 2022). Written informed consent was obtained from all participants and their parents or legal guardians. Confidentiality and anonymity were strictly maintained. All procedures complied with the Declaration of Helsinki.

Anthropometric and Physiological Measurements

Anthropometric Measurements

Anthropometric data were collected following World Health Organization (WHO, 2020) standards. For female adolescents with ID, instructions were simplified. The following variables were measured: body weight, height, and body mass index (BMI).

Body Weight

Body weight was measured using a calibrated SECA 700 mechanical scale placed on a flat surface. Participants wore light clothing and no shoes. They stood upright in the center of the scale with arms relaxed at their sides. Measurements were recorded after stabilization. When movement occurred, the measurement was repeated. Body weight was recorded to the nearest 0.05 kg.

Height

Height was measured using a SECA 213 portable stadiometer. Participants stood barefoot with heels together and body aligned. Heels, buttocks, scapulae, and occiput were positioned against the stadiometer when possible. The head was maintained in the Frankfurt plane. Measurements were taken at the end of a normal inspiration and recorded to the nearest 0.1 cm. Measurements were repeated if posture was unstable or instructions were not fully understood. Height was recorded to the nearest 0.1 cm

Body Mass Index

BMI (kg/m^2) was calculated as weight (kg) divided by height squared (m^2).

Physiological Measurements

Physiological assessments followed World Health Organization guidelines for standardized measurements (WHO, 2020). Female adolescents with ID received simplified instructions, and measurements were repeated whenever necessary to ensure reliability. The following variables were assessed: heart rate, respiratory rate, blood pressure, and VO_2max.

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Heart Rate

Resting heart rate was measured in a seated position after 5 minutes of rest using a validated pulse oximeter (Masimo MightySat). The sensor was placed on the finger and maintained for 60 seconds. Measurements were repeated when signal instability or participant movement was observed. Results were recorded in beats per minute (bpm), with ±1 bpm accuracy.

Respiratory Rate

Respiratory rate was measured at rest in a seated and relaxed position after a 5-minute rest period. Thoracoabdominal movements were observed for 60 seconds using a digital stopwatch (Casio HS-80TW). Care was taken to avoid influencing the participants' spontaneous breathing pattern. Measurements were repeated when disturbances occurred. Results were expressed in breaths per minute.

Blood Pressure

Blood pressure was measured after 5 minutes of rest with participants seated and the arm supported at heart level. A validated automated sphygmomanometer (Omron HBP-1300) with an appropriate cuff size was used. Two measurements were taken at 1–2 minute intervals, and the mean value was used for analysis. Values were expressed in mmHg (±3 mmHg accuracy).

VO_2max Assessment

Cardiorespiratory fitness was assessed using the 20-m shuttle run test according to the protocol of Léger et al. (1988). Participants ran back and forth between two markers placed 20 meters apart, following audio signals with progressively increasing speed. The test was terminated when the participant reached voluntary exhaustion or failed to reach the line on two consecutive occasions. The test was conducted on a flat, non-slip surface under supervision. Appropriate sports shoes were worn. The final completed stage and running speed were recorded to estimate VO_2max. VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) was calculated using the following equation: $VO_2max = 31.025 + (3.238 \times V) - (3.248 \times Age) + (0.1536 \times V \times Age)$ where V represents running speed: $V\ (km/h) = 8.5 + (0.5 \times \text{number of completed stages})$

Procedures

Standardized procedures were applied to ensure consistency:

- Written informed consent was obtained from parents or guardians, and participants received standardized instructions before testing.
- Assessments followed this sequence: anthropometry → 5-minute rest → physiological measurements → VO_2max test;
- All measurements were conducted between 7:45 a.m. and 11:15 a.m. under standardized school conditions;

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- All exercise tests were supervised by trained investigators to ensure participant safety.
- Participants with ID completed familiarization sessions prior to VO_2max testing.

Statistical Analysis

Data were screened for completeness and accuracy prior to analysis. Statistical analyses were performed using Jamovi software (version 2.6.44). Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances using the Levene test. When assumptions were not met, Welch's *t*-test or the Mann–Whitney *U* test was applied. Group comparisons were performed using independent Student's *t*-tests, and effect sizes were calculated using Cohen's *d*. Pearson correlation analyses were used to examine relationships between age, anthropometric variables, physiological parameters, and VO_2max, after confirming linearity and absence of significant outliers. Multiple linear regression was performed to identify predictors of VO_2max. Variables considered clinically relevant or statistically associated with VO_2max in the bivariate analyses were entered into the multiple linear regression model. Standardized beta coefficients (β), 95% confidence intervals, and variance inflation factors (VIF) were reported. All statistical tests were two-tailed, and statistical significance was set at $p < .05$. All analyses followed STROBE guidelines to ensure methodological rigor in observational research.

RESULTS

As shown in Table 1, female adolescents with intellectual disability had significantly higher body weight, body mass index (BMI), respiratory rate (RR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) than their peers without intellectual disability (all $p < .05$). They were also significantly shorter and demonstrated lower VO_2max values (both $p < .001$). Although the mean heart rate was higher among female adolescents with intellectual disability (93.99 ± 6.2 bpm) than among those without intellectual disability (91.69 ± 12.6 bpm), this difference did not reach statistical significance ($p = .066$).

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Table 1. Comparison of anthropometric, physiological and physical condition parameters between females' adolescents with and without intellectual disability

	Groups		Statistics (independent Student's t-test)	*P*	Effect Size (Cohen's d)
Parameters	Female with ID(n=129) Mean±SD	Female without ID (n=123) Mean±SD			
Weight (kg)	38.26±3.2	36.30±3.3	4.78	<.001	0.602 [0.35, 0.85]
Height (m)	1.58±0.01	1.61±0.08	-4.03	<.001	-0.508 [-0.75, -0.25]
BMI (kg/m²)	23.50±2.7	20.83±2.5	8.03	<.001	1.012 [0.74, 1.27]
Heart rate (bpm)	93.99±6.2	91.69±12.6	1.85	0.066	0.233 [-0.01, 0.48]
RR (cpm)	18.44±1.1	17.49±1.1	6.69	<.001	0.843 [0.58, 1.10]
SBP (mmHg)	117.36±1.6	115.35±1.7	9.56	<.001	1.204 [0.93, 1.47]
DBP (mmHg)	78.65±2.9	77.76±2.0	2.84	0.005	0.358 [0.10, 0.60]
VO_{2max} (ml/kg/min)	26.03±4.1	29.11±4.6	-5.59	<.001	-0.705 [-0.95, -0.45]

ID: intellectual disability, HR: heart rate, RR: respiratory rate, SBP: systolic blood pressure, DBP: diastolic blood pressure, BMI: body mass index

Table 2 illustrates the Pearson correlation matrix among the anthropometric and physiological variables. VO_2max showed a very strong positive correlation with age (r = .922, p < .001) and moderate positive correlations with respiratory rate (r = .468, p < .001), heart rate (r = .366, p < .001), and systolic blood pressure (r = .366, p < .001). In contrast, body mass index was not significantly correlated with VO_2max (r = .035, p = .579). The physiological variables were also positively interrelated, particularly respiratory rate with systolic blood pressure (r = .650, p < .001), respiratory rate with heart rate (r = .408, p < .001), and heart rate with systolic blood pressure (r = .401, p < .001). These findings indicate that higher respiratory and cardiovascular responses are associated with greater aerobic capacity, whereas BMI does not show a significant bivariate association with VO_2max in this sample (Table 2).

Table 2. Associations between age, anthropometric parameters, physiological parameters and VO_2 max

Variable	1	2	3	4	5	6
1. Age	—					
2. BMI	.205*	—				
3. HR	.833***	.164**	—			
4. RR	.754***	.269***	.408***	—		
5. SBP	.730***	.444***	.401***	.650***	—	
6. VO_2max	.922***	.035	.366***	.468***	.366***	—

Note. BMI = body mass index; HR = heart rate; RR = respiratory rate; SBP = systolic blood pressure; VO_2max = maximal oxygen uptake. *p* < .05. p < .01. *p* < .001.

The table 3 shows that VO_2max is positively correlated with respiratory rate and heart rate, whereas BMI is negatively correlated with aerobic capacity. Although systolic blood pressure showed a positive trend, its association with VO_2max was weaker and was not statistically significant in the multivariable regression model. These findings suggest that respiratory and cardiovascular responses are more strongly related to aerobic capacity than resting systolic blood pressure in the studied participants (Tableau 3).

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Table 3. Multiple linear regression analysis of predictors of VO_2max among female adolescents with intellectual disability (n = 129).

Predictor	B	SE	β	95% CI for B	T	*P*	VIF
Intercept	-48.6000	19.2107	-	**[**-86.25, -10.95**]**	-2.53	0.012	
Height (m)	8.33	4.20	0.11	[0.10, 16.56]	1.98	0.049	1.05
BMI (kg/m²)	-0.19	0.09	-0.12	[-0.37,-0.01]	-2.00	0.046	1.30
HR(bpm)	0.08	0.02	0.18	[0.04, 0.12]	3.13	0.002	1.26
RR (breaths/min)	1.26	0.27	0.33	[0.73, 1.79]	4.63	<.001	1.82
SBP (mmHg)	0.31	0.18	0.13	[-0.04, 0.66]	1.70	0.091	2.08

$R=0.53$, ajusted $R^2=0.28$,HR: heart rate, RR: respiratory rate, SBP: systolic blood pressure, SE : standard error, B: unstandardized regression coefficient ; β: standardized regression coefficient, VIF, variance inflation interval, n=129

DISCUSSION

The results of this study reveal marked differences between female adolescents with intellectual disability (ID) and their peers with typical development, particularly in anthropometric characteristics, physiological responses, and cardiorespiratory fitness. Overall, these findings indicate a less favorable cardiometabolic and functional health profile among female adolescents with ID.

Female adolescents with ID presented significantly higher body weight, shorter stature, and increased body mass index (BMI), indicating a higher level of adiposity compared with the control group. These findings are consistent with previous international studies reporting a higher prevalence of overweight and obesity among youth with ID (Must et al., 2023; Ungurean et al., 2023; Podgorska-Bednarz et al., 2024).

Comparable findings have also been reported in African populations, where nutritional transition and insufficient physical activity contribute to excess body weight in this vulnerable group (Afolabi et al., 2021). In addition, the positive associations observed between BMI, body weight, and blood pressure support the hypothesis of elevated cardiometabolic risk among adolescents with ID, in agreement with WHO recommendations and previous epidemiological evidence (WHO, 2020). Cardiorespiratory fitness was also significantly lower in female adolescents with ID, as reflected by reduced VO_2max values. This result aligns with previous studies indicating that low physical activity levels, reduced motor competence, and functional limitations negatively affect aerobic capacity in individuals with ID (Vilelmine et al., 2024). Although BMI was negatively associated with VO_2max, the bivariate correlation was weak and not statistically significant, suggesting that aerobic fitness is influenced not only by body composition but also by functional and behavioral factors such as ventilatory efficiency and engagement in physical activity (Carayanni et al., 2022; Smouter et al., 2019).

The multiple regression analysis provided additional insight into the determinants of VO_2max. The multiple linear regression model explained approximately 28% of the variance in VO_2max (adjusted $R^2 = 0.28$), indicating a moderate explanatory capacity. Among the predictors, respiratory rate (RR) emerged as the strongest determinant, followed by heart rate (HR). These findings suggest that functional adaptations of the respiratory and cardiovascular

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systems play a more important role in aerobic performance than morphological characteristics alone. Similar observations have been reported in previous studies emphasizing the importance of ventilatory and cardiovascular efficiency in adolescent physical performance (Roger et al., 2023; Maicas Pérez et al., 2024; Raghuveer et al., 2020).

In contrast, systolic blood pressure was not identified as a significant predictor of VO_2max, indicating that its independent contribution to aerobic performance was not statistically significant after adjustment for the other predictors.

The Pearson correlation analysis further demonstrated the important role of age, which was significantly associated with several physiological variables, including HR, RR, systolic blood pressure (SBP), diastolic blood pressure (DBP), and VO_2max. These associations likely reflect the influence of biological maturation on physiological and functional responses during adolescence, consistent with international recommendations for adolescent health assessment (WHO, 2020).

Finally, the strong relationships observed between respiratory rate, heart rate, and blood pressure illustrate the close interaction between the respiratory and cardiovascular systems. However, the lower VO_2max observed among female adolescents with ID may reflect less efficient cardiorespiratory adaptation than that of their peers without ID. This interpretation is supported by both African and European studies describing functional limitations and reduced exercise capacity in youth with ID (Rotenberg et al., 2024 ; Wibowo et al., 2026).

Clinical implications

These findings suggest that female adolescents with ID may be at increased cardiometabolic risk, highlighting the need for closer clinical monitoring.

The statistically significant role of BMI and cardiovascular parameters indicates that early screening for overweight, hypertension, and poor cardiorespiratory fitness should be routinely considered in this population. Regular assessment of cardiorespiratory fitness using VO_2max estimation or validated field tests

These findings also support the inclusion of comprehensive cardiorespiratory assessments that evaluate physiological responses to exercise in addition to resting measurements.

Practical implications

From a public health and rehabilitation perspective, these findings highlight the need to design appropriate physical activity programs focused on improving cardiorespiratory capacity.

Interventions should prioritize progressive endurance exercises, enjoyable and individualized approaches, and target adiposity reduction and VO_2max improvement.

The importance of ventilatory variables also indicates the need to include exercises designed to improve respiratory endurance and ventilatory efficiency.

However, a multidisciplinary approach involving healthcare professionals, educators, and families is essential to ensure the effectiveness and sustainability of interventions.

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Limitations and perspectives

This study has several limitations, notably its cross-sectional nature which did not allow for the establishment of causal relationships, and the absence of variables such as the level of physical activity, dietary habits and other cardiometabolic parameters such as blood glucose and lipid profile measurements limited the interpretation of the findings.The regression model, although significant, explained only part of the variance in VO_2max.
Future studies should therefore adopt longitudinal approaches, integrate objective measures of physical activity, include metabolic biomarkers, and test targeted interventions.

CONCLUSION

The present study highlights an unfavorable health profile in female adolescents with intellectual disability, marked by increased adiposity, reduced cardiorespiratory capacity and alterations in cardiovascular parameters.
The combined comparative, correlational, and predictive analyses demonstrated that respiratory rate, heart rate, and BMI were the principal independent predictors of VO_2max, whereas systolic blood pressure was not independently associated with aerobic capacity.
These results highlight the need to develop early, multidimensional and tailored intervention strategies aimed at improving physical fitness and reducing cardiometabolic risks.
Looking ahead, a better understanding of behavioral, physiological, and environmental factors will enable clinicians and policymakers to optimize interventions and sustainably improve the health and adaptive behavior of adolescent girls with ID.

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