Test-Retest Intra-Session Reliability of Isokinetic Knee Strength Measurements in Obese Children

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Received: 8 June 2020; Accepted: 21 August 2020; Published: 26 August 2020

Abstract: Background: Childhood obesity is one of the most critical global health challenges. Poor knee extensor strength is associated with disability and difficulties with physical function in obese patients. The objective of this study was to evaluate the test-retest reliability of peak torque and total work in concentric flexion and concentric extension in obese children. Methods: 25 obese children aged between 6 and 11 years performed 3F maximal unilateral isokinetic repetitions with the knee extensors/flexors performing concentric actions at 60°/s. Peak torque (Nm), total work (J), and the ratio antagonist/agonist were recorded and normalized by total and lean mass. The intraclass correlation coefficient (ICC), standard error of measurement (SEM), and smallest real difference (SRD) were computed. Results: Reliability was excellent for almost all variables. The highest ICC values were observed when work or peak torque were not divided by any other variable. However, SEM (%) and SRD (%) were lower when peak torque and work were divided by the total mass or lean mass. The antagonist/agonist ratio showed an ICC value of 0.873. Conclusion: Peak torque, total work, and the antagonist/agonist ratio are reliable in obese children.

Keywords: isokinetic strength; children; obesity; reliability

1. Introduction

The prevalence of obesity has grown in recent decades and has become one of the most critical global health challenges. Obese children have an increased risk of becoming obese adults [1] and are more likely to present with other health problems such as hyperlipidemia, hypertension, glucose intolerance, and sleep disturbances [2]. Furthermore, the prevalence of lower limb and low back pain is also higher among obese children [1].

Childhood obesity may affect gait and posture by reducing knee and hip flexion during walking and increasing joint moments at the hip, knee, and ankle joints [3,4]. These adaptations may increase the risk of injuries, falls, and the development of these diseases [3]. Lower limb strength is important for reducing movement problems in obese children. Among other examples, poor knee extensors’ strength has been related to disability and difficulties for the physical function of obese women [5].

The gold standard method of strength assessment is isokinetic dynamometry. Previous studies have used this technique to evaluate strength in obese children and adolescents [6–8]. Abdelmoula, et al. [9]
reported that obese children present higher maximum voluntary contraction than non-obese adolescents. However, it is controversial since sedentary obese people may show lower strength levels [10], and their muscle fibers may have more intramyocellular lipids, which could lead to poorer performance [11].

For a correct interpretation of the results after a physical condition assessment test, it is necessary to know how reliable this test is. The following aspects may affect the reliability of an isokinetic strength evaluation: (1) The accuracy of the isokinetic dynamometer, (2) experience of the assessment, (3) fatigue, (4) motivation, (5) inexperience of the person evaluated in the test (learning effect), and (6) the natural human variability. In this regard, the test-retest reliability of isokinetic strength in non-obese children has been previously described [12–14]. However, to the best of our knowledge, there is no study evaluating the test-retest reliability of isokinetic strength in obese children. It seems that the functional performance of obese and non-obese children may be different, and this could lead to differences in the reliability of the test. Some of the differences in strength between obese and normal-weight children in the scientific literature are the following: (1) Obese children show a deficit of knee extensors strength linked to their mass [7]; (2) relative strength expressed per unit of body mass may be lower in obese children [15]; (3) Obese children have reduced knee flexion angles in the starting position before starting to walk [16]; (4) “the overweight/obese children had poorer muscle tissue composition, greater velocity-related impairments in muscle strength, and a smaller range of mean firing rates at the targeted torque that may suggest altered motor unit recruitment strategies” [17].

In particular, it is necessary to know test-retest intra-session reliability since several interventions have been proposed, such as whole-body vibration, that could have an acute effect on the knee strength. To verify what the real acute effect of the training is, it is essential to know the test-retest intra-session reliability of the isokinetic knee strength.

Therefore, the main objective of the present study was to evaluate the test-retest reliability of peak torque and total work in concentric flexion and concentric extension in obese children aged between 6 and 11. Furthermore, given that these measures are sometimes reported as normalized variables (divided by weight or lean mass), as a secondary objective, we intended to verify whether reliability can be affected by this normalization.

2. Materials and Methods

2.1. Participants

The sample size was calculated to achieve a power of 0.90 for the intraclass correlation coefficient (ICC). The minimum acceptable reliability was that the ICC was 0.70, which means good reliability following the classification by Munro, et al. [18], while the expected reliability based on previous studies [19] was that the ICC was 0.90, which means excellent reliability. The alpha value was set at 0.05. A total of 25 participants were required [20].

Therefore, purposive sampling was used to select 25 obese children. The inclusion criteria were: (a) Body mass index (BMI) equal to or greater than the 95th percentile [21] for age and sex, and (b) age between 6 and 11 years. Table 1 summarizes the main characteristics of the participants. The parents of all children completed an informed consent form. The local Bioethics and Biosecurity Committee approved the study protocol, which included the tasks reported in the present article. The study was performed following the principles of the Declaration of Helsinki.
Table 1. Characteristics of the children who have been included in the study.

|                        | All Children (n = 25) | Boys (n = 11) | Girls (n = 14) |
|------------------------|-----------------------|---------------|---------------|
| Age (years)            | 8.00 ± 1.32           | 7.90 ± 1.57   | 8.07 ± 1.14   |
| Height (cm)            | 136.60 ± 9.10         | 136.70 ± 10.45 | 136.52 ± 8.29 |
| Bone Mass (kg)         | 1.05 ± 0.17           | 1.08 ± 0.15   | 1.02 ± 0.18   |
| Fat Mass (kg)          | 17.04 ± 4.65          | 15.63 ± 4.87  | 18.14 ± 4.32  |
| Lean Mass (kg)         | 24.83 ± 4.15          | 25.37 ± 4.96  | 24.41 ± 3.53  |
| Lean Mass and Bone Mass (kg) | 25.89 ± 4.28       | 26.45 ± 5.09  | 25.44 ± 3.67  |
| Total Mass (kg)        | 42.96 ± 8.08          | 42.09 ± 9.34  | 43.64 ± 7.23  |

2.2. Measures

Body composition was measured using dual-energy X-ray absorptiometry (DEXA—Hologic QDR, Hologic, Inc., Bedford, MA, USA). These measures involved bone mass, fat mass, and lean mass. Quality assurance for DXA, including calibration, was performed using the standard provided by the manufacturer.

An isokinetic dynamometer (Biodex System 3—Biodex Corp., Shirley, NY, USA) was used for assessing knee strength. The velocity of the test can also be controlled with this device.

2.3. Design and Procedures

The study used a test-retest reliability design.

Only the dominant leg was tested. To define this, participants were asked for their preferred kicking leg. After a 15 min warm-up, including articular mobilization and stretching, peak torque (PT) and total work (TW) during three maximal repetitions at 60°/s were recorded for knee extensors/flexors. Verbal encouragement was provided as stimulation to encourage the subjects to produce the maximal effort. This testing velocity has previously been used in reliability studies with children [12,14] and was based on the ability of children to generate greater torque at this velocity compared with other faster velocities [22]. The weight of the limb was recorded using the dynamometer software, and gravity adjustments were made.

The participants were asked to sit on the Biodex System 3 with the seatback at an angle of 85° to the seat. The hands grabbed the side supports of the seat that were intended for the test in the best conditions. A standardized protocol was followed, with the mechanical axis of the dynamometer aligned with the axis of movement of the knee [23].

Three repetitions were performed in one single session. The first repetition was for familiarization purposes. The second repetition was then considered the “test repetition”, and the third was the “retest repetition”.

The antagonist/agonist ratio (PT of knee flexor muscles/PT of knee extensor muscles) was also calculated. The ratio was not calculated with the variables divided by total mass or lean mass because these 2 mass variables did not change between test and retest, thus they did not affect the ratio. All tests were conducted by an expert researcher.

2.4. Statistical Analysis

Reliability analyses were performed following the recommendations of Weir [24]. Relative reliability was determined using the ICC 3,1 (2-way mixed, single measures) with 95% confidence intervals for the 2 repetitions [25]. Absolute reliability was estimated by calculating the Standard Error of Measurement (SEM) and the Smallest Real Difference (SRD). The SEM was calculated as follows: $SEM = SD \cdot \sqrt{1-ICC}$ where SD is the mean SD of the 2 repetitions. The SRD was $1.96 \cdot SEM \cdot \sqrt{2}$. SEM and SRD were converted into percentages to facilitate further comparisons with other studies.

The following classification was used for the interpretation of the ICC [18]: An ICC lower than 0.5 corresponded to poor reliability, an ICC from 0.5 to 0.7 corresponded to moderate reliability,
an ICC from 0.7 to 0.9 corresponded to good reliability, an ICC greater than 0.9 corresponded to excellent reliability.

Bland–Altman analysis was performed to show the level of agreement between test and retest in both peak torque and work. Plots show “the bias” and limits of agreement (LOA) calculated to 95%. Bias values close to zero represented strong agreement, and the smaller range between these 2 LOA were interpreted as better agreement.

PT and TW were also analyzed as mean values divided by total mass (kg) and lean mass (kg). The significance level was determined at $p < 0.05$.

3. Results

Table 2 summarizes the differences between test and retest measures. Paired $t$-test analyses showed that there was only a significant difference in one variable: TW divided by total mass in the concentric extension ($p = 0.046$). The rest of the variables did not significantly change from the test to the retest.

| Test Measurement                  | Peak Torque (Nm) | Work (J) |
|----------------------------------|------------------|----------|
|                                  | Test             | Retest   | $P$    | Test              | Retest   | $p$  |
| Concentric Extension Test        | 58.16 ± 21.49    | 57.12 ± 21.45 | 0.175 | 59.28 ± 22.41     | 57.47 ± 22.01 | 0.070 |
| Concentric Flexion Test          | 29.08 ± 10.38    | 29.11 ± 9.52  | 0.963 | 29.91 ± 11.93     | 30.35 ± 11.14 | 0.669 |

| Test Measurement                  | Peak Torque (Nm) | Work (J) |
|----------------------------------|------------------|----------|
|                                  | Test             | Retest   | $P$    | Retest           | Test             | $p$  |
| Concentric Extension Test        | 1.34 ± 0.38      | 1.32 ± 0.39 | 0.164 | 1.37 ± 0.39      | 1.32 ± 0.37      | 0.046 |
| Concentric Flexion Test          | 0.68 ± 0.20      | 0.68 ± 0.17 | 0.892 | 0.70 ± 0.24      | 0.70 ± 0.22      | 0.762 |

| Test Measurement                  | Peak Torque (Nm) | Work (J) |
|----------------------------------|------------------|----------|
|                                  | Test             | Retest   | $P$    | Retest           | Test             | $p$  |
| Concentric Extension Test        | 2.31 ± 0.64      | 2.27 ± 0.65 | 0.157 | 2.35 ± 0.66      | 2.28 ± 0.65      | 0.053 |
| Concentric Flexion Test          | 1.17 ± 0.34      | 1.17 ± 0.29 | 0.955 | 1.20 ± 0.41      | 1.21 ± 0.37      | 0.740 |

$p$-values of paired $t$-test; Nm = Newton x meter; J = Joules.

Table 3 shows the ICC, SEM, and SRD of each variable. Based on ICC values, the reliability was excellent for all variables except two: Total work divided by total mass in the concentric flexion, and total work divided by lean mass in the concentric flexion.

The highest ICC values were observed when total work and peak torque were not divided by any other variable. However, SEM (%) and SRD (%) were lower when PT and TW were divided by total mass or lean mass. SEM (%) oscillated from 4.41% to 7.17% for PT, and from 5.91% to 13.70% for TW. Similar differences were also observed in SRD (%) values.

Table 4 shows the ICC, SEM, and SRD of PT antagonist/agonist Ratio. Based on ICC values, the reliability was “good” for Peak Torque Ratio. SEM (%) was 8.62% and SRD (%) was 23.91%.
Table 3. Reliability of isokinetic concentric knee measurements (n = 25).

| Test Measurement      | Peak Torque (Nm) | Work (J) |
|-----------------------|------------------|----------|
|                       | ICC (95% CI)     | SEM (Nm) | SEM (%) | SRD (Nm) | SRD (%) | ICC (95% CI)     | SEM (Nm) | SEM (%) | SRD (Nm) | SRD (%) |
| Concentric Extension Test | 0.984 (0.965–0.993) | 2.71     | 4.71    | 7.52     | 13.06    | 0.975 (0.944–0.989) | 3.51     | 6.01    | 9.73     | 16.67    |
| Concentric Flexion Test     | 0.956 (0.905–0.980) | 2.08     | 7.17    | 5.78     | 19.88    | 0.908 (0.804–0.958) | 3.49     | 11.61   | 9.69     | 32.18    |
| Concentric Extension Test     | 0.977 (0.950–0.990) | 0.05     | 4.41    | 0.16     | 12.23    | 0.957 (0.906–0.981) | 0.08     | 5.96    | 0.22     | 16.52    |
| Concentric Flexion Test       | 0.938 (0.866–0.972) | 0.04     | 6.96    | 0.13     | 19.29    | 0.894 (0.776–0.951) | 0.07     | 10.8    | 0.21     | 29.95    |

ICC: Intra-class Correlation Coefficient; CI: Confidence Interval; SEM: Standard Error Measurement SRD: Small Real Difference; Nm = Newton x meter; J = Joules.
Table 4. Summary and reliability of isokinetic peak torque ratio at 60°/s on two occasions (n = 25).

| Test Measurement          | Test       | Retest     | \( p \) | ICC (95% CI) | SEM (Nm) | SEM (%) | SRD (Nm) | SRD (%) |
|---------------------------|------------|------------|---------|--------------|-----------|---------|----------|---------|
| Peak Torque Ratio         | 0.51 ± 0.12| 0.53 ± 0.13| 0.202   | 0.874 (0.738–0.942) | 0.04      | 8.62    | 0.12     | 23.91   |

\( p \)-values of paired t-test; ICC: Intra-class Correlation Coefficient; CI: Confidence Interval; SEM: Standard Error Measurement SRD: Small Real Difference.

Figure 1 shows Bland–Altman plots peak torque. Bland–Altman plots indicated that none of the points were outside the 95% LOA.

Figure 2 shows the Bland–Altman plots work. Bland–Altman plots indicated that the points outside the 95% LOA were 6% for both extensors and flexors.
4. Discussion

The main finding of this study was that the reliability of strength values was very high. The values of the ICC from concentric extension were always higher than 0.95. Furthermore, the reliability of the concentric flexion oscillated between 0.887 and 0.956. This difference between flexors and extensors was common in previous studies on the reliability of concentric flexion and extension \[12,13\] and may indicate a poorer ability to exert controlled concentric force with knee flexors. Therefore, after one single familiarization repetition, the second and third repetitions were not different \( (p > 0.05) \), and the reliability was good or excellent \( (ICC > 0.7 \text{ and } 0.9, \text{ respectively}) \). These results were similar to those observed in other studies, which were summarized in the study by Muñoz-Bermejo, Pérez-Gómez, Manzano, Collado-Mateo, Villafaina and Adsuar \[19\].

The PT values of knee flexors reported in Table 2 were similar to those reported by a previous study with 3587 children \[22\]. However, the PT of knee extensors was higher in the obese children in the present study compared with the 50th percentile of the previous study. Absolute strength was greater in obese subjects. However, when the data were normalized (e.g., by muscle volume), strength decreased in obese subjects. Therefore, it is commonly accepted that obesity increases absolute strength,
probably as the greater cross-section mass is lower. This may suggest a deficit in contractile muscle function that is compensated for by increased muscle mass [26–28]. The present study included not only reliability indices for non-normalized PT and TW, but also normalized by total body mass and lean mass. To our knowledge, this is the first article reporting on the reliability of strength variables during an isokinetic test in a sample comprised of obese children.

The incidence of knee injuries in obese children is higher than in non-obese children [29]. The balance of knee flexor and extensor muscles is suggested to be a relevant marker of the capacity for stabilization of the knee and the reduction of risk of injury [30,31]. The present study assesses the hamstrings/quadriceps balance ratio using the PT of a maximum voluntary contraction. Results showed that the mean hamstring/quadriceps ratio was 51.56 and 53.22 in the test and retest, respectively. This ratio showed good reliability, with an ICC close to 0.90 (0.874), a SEM of 8.62%, and a SRD of 23.91%. However, those mean values are lower than those found for non-obese children in a previous study [32], which may indicate that, to some extent, the higher incidence of knee injury in obese children may be partially explained by a greater imbalance between knee flexor and extensor muscles. However, further studies are needed to test that hypothesis.

Visual inspection of the Bland–Altman plot for peak torque and work did not show signs of any systematic bias in the differences between test and retest. Our data showed that the work may have higher variability than peak torque in obese children. It appears that the percentage differences in the normalized torque values tend to decrease with higher levels of normalized torque. This may suggest poorer reliability in those with lower levels of muscle strength. In this sense, it is important to evaluate the intra-session test-retest reliability of isokinetic knee strength in this population because they could have knee extensor strength deficits [7] and the strength per unit of body mass may be lower, which could have implications for weight-bearing activities [15]. In this way, our study could help to adequately interpret measurements on muscle strength, which is related to their physical autonomy, the ability to perform daily activities, and their health-related quality of life [16]. Additionally, the results obtained in our study may be used to interpret the acute effects of physical training on the peak torque and work of knee extensors and flexors. For example, in the evaluation of acute changes after a single training session (e.g., whole-body vibration—WBV [33]) aimed to improve the peak torque and work of the flexors and extensors of knees, it could only be concluded that the peak torque improved, when the increment was higher than 19.88% in the flexors and higher than 13.06% in the extensors. Regarding work, the improvement should be higher than 32.18% in the flexors and higher than 16.67% in extensors.

The current study has several limitations. First, only intra-session reliability was assessed. Thus, reliability values reported in the present study may vary when the test and retest are performed with a longer period of time between each other. Second, a concentric-concentric test was performed for both hamstrings and quadriceps. A mixed ratio eccentric/concentric hamstring-to-quadriceps may provide further information since it is also related to knee injuries [34]. Third, only the dominant lower limb was assessed. The same test with the non-dominant leg may present lower reliability [13]. Fourth, we have not assessed the potential effects of maturation/developmental stage, and finally, we did not have access to the activity level/exercise history of these participants. Furthermore, future studies are also encouraged to evaluate the torque ratio at various joint angles, such as evaluating the PT at a specific angle for both flexion and extension.

5. Conclusions

The reliability of PT and TW of the dominant knee flexor and extensor muscles is good to excellent in obese children, and the reliability of the concentric flexion was slightly lower than the reliability of concentric extension in obese children.

Author Contributions: D.C.-M.: Conceptualization, software, and writing—original draft. F.J.D.-M.: Data curation, methodology, and writing—original draft. J.C.A.: Conceptualization, formal analysis, visualization, and writing—review and editing. J.A.P.: Data curation, funding acquisition, project administration,
and writing—original draft. P.T.-C.: Formal analysis, methodology, validation, and writing—review and editing.
M. Á.G.-G.: Funding acquisition, methodology, and writing—original draft. A.M.R.: Data curation, validation,
writing—original draft and writing—review and editing. All authors have read and agreed to the published
version of the manuscript.

Funding: This research is funded by the Extremadura Public Employment Service (SEXPE), grant number #TE311
0009-18; and by “Instituto Português do Desporto e Juventude”: UÉvora—UniversCIDADE V (696/DDT/2019).

Acknowledgments: We are very grateful to all the participants in this study.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the
study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to
publish the results.

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