THE RELIABILITY OF BALANCE ASSESSMENT TESTS IN ADOLESCENT ATHLETES: A SYSTEMATIC REVIEW

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Abstracts

Introduction: The growth spurt in adolescents is typically identified by peak skeletal growth rates, which resulted in different anatomical and physiological functions compared with adults, thus could affect the dynamic postural control and increasing the vulnerability to injury. However, the available balance assessment is mostly only applicable to adults, and the implementation for the adolescent population is still questionable; hence this study aims to identify the most reliable balance assessment for adolescent athletes. **Methodology**: A systematic review of reliability studies that were obtained from 5 electronic databases: PubMed, Scopus, Web of Science, EBSCOhost, and Ovid MEDLINE. The study article was assessed using the Quality Appraisal of Reliability Studies (QAREL) scale. **Research findings**: The initial search resulted in 753 articles, where five studies were then extracted and examined using the QAREL scale. These five studies consisted of three balance assessments, including Y-Balance Test in three studies, and the rest are Dual Task Postural Control Testing, and Tandem Gait Test. The highest score was 87.5% from a study by Greenberg et al., which assessed the Y-Balance Test. **Conclusions**: The most reliable balance assessment tool according to the QAREL scale was the Y-Balance Test.

Keywords: balance assessment, athletes, adolescent, reliability

1. Introduction

Adolescence represents one of the most rapid phases of human development in which many biological changes occur[1]. The growth spurts in adolescents are typically identified by the peak skeletal growth rates[2]. The noticeable physical changes will be in the form of height increase, muscle mass gain, body fat distribution, and the

development of secondary sexual characteristics. This sequence of changes seems universal but varies significantly with its time and speed in adolescence[1].

Adolescents' physical and mental aspects are quantitative and qualitatively not the same as adults, so they need to be considered not as smaller but different. They are growing through a maturation process affecting their ability to learn specific motor skills[3]. Differences in anatomical and physiological functions in adolescents compared with adults can affect postural control and increase susceptibility to injury[2].

Balance or postural control is the ability to maintain the body's center of gravity (CoG) vertically on a base of support and is influenced by the rapid and continuous response of coordinated visual, vestibular, somatosensory, and neuromuscular structures[4]. Balance could be explained as static and dynamic balance[5]. Static balance is maintaining a base of support with minimal movement. In contrast, dynamic balance is the ability to maintain a stable position when performing some tasks or activities[6].

Balance is an important aspect to be considered for athletes. The occurrence of changes in adolescence affects the ability of postural control possessed. Poor postural control or balance is associated with a higher risk of sports-related injury[6]. In comparison, a good balance can reduce the risk of body imbalance, fall, or subsequent injury and support optimal motor performance in several sports[4].

Regular balance assessments, both static and dynamic for athletes, are an essential instrument to set and tailor the right training program by considering the sport specific, the athlete's age, and the results of regular balance assessments that have been carried out. In clinical practice and sports, balance assessment can be carried out using several tests or indexes. Generally, an appropriate balance examination method for athletes is based on the goals and results

aimed to achieve [3]. Static balance assessment could be done using several simple tests such as Single Leg Stance Test, Stork Test, Romberg Test, and Tandem Romberg Test. Meanwhile, dynamic balance is usually evaluated by the Star Excursion Balance Test (SEBT), the Y-Balance Test (YBT), Balance Error Scoring System (BESS), and Functional Reach Test [4,7].

Most studies previously examined the reliability of specific balance assessment instruments in adult athletes. Meanwhile, balance assessment outcome measures should reflect the functional change that may occur during adolescence's rapid growth. Furthermore, only a few studies discuss balance assessment instruments in adolescent athletes, and no studies compare the reliability to suggest the most reliable measuring instrument. Therefore, the purpose of this study was to investigate the most reliable balance assessment in adolescent athletes based on the available study.

2. Methods

2.1. Research Design

This study is a systematic review of reliability studies.

2.2. Search Strategy

The authors searched the articles through five electronic databases, such as: PubMed, Scopus, Web of Sciences, EBSCOHost, and Ovid Medline. The keywords of the search were: balance assessment, athletes, adolescent, reliability.

2.3. Eligibility Criteria

The reliability studies included in this study were the ones that was published up to July 10th 2022, with inclusion criteria as follows: (1) the study population are adolescents (aged 10-19 years old); (2) one of the outcome measure is the reliability of balance assessment tool; (3) the full-text were published in English.

Meanwhile, the exclusion criteria were: (1) the study that involving subjects with existing lower extremity injury or other conditions that may alter balance performance; (2) full text is unavailable, which only available in the form of abstract, dissertation, conference proceeding, editorials, opinion pieces, review papers, letters, single-case studies, short communication or technical notes.

2.4. Assessing Quality of Studies

The quality assessment of the included studies was Quality Appraisal of Reliability Study (QAREL) scale developed by Nicholas et al. (2009). The QAREL is a scale that specifically designed for reliability studies and evaluate statistical methods[9,10]. The QAREL consists of an 11 item checklist and all items are weighted equally and scored using Yes, No, Unclear, or N/A in accordance with scoring guidelines[9,10]. The studies then rated based on the percentage of Yes with highest percentage considered as the most reliable measurement tool[9,10].

2.5. Data Extraction

The extracted information from each articles were: author, country, aim of the study, sample size, age mean, gender, outcome measures, and reliability outcome (refer to Table 1).

3. Results

The search process from five databases resulted in 753 articles. After removing duplicates, 733 were to be eliminated through the eligibility based on title, abstract, and full-text. This selection process finally resulted in five articles to be further reviewed. The details of the articles' selection process can be seen in PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) flow chart at Figure 1.

3.1. Characteristics of The Studies

The balance assessment tools identified in this study are Y-

Balance Test, Dual Task Postural Control Testing, and Tandem Gait Test. The number of involved subjects in this study ranged from nine to 110, consisting of female and male adolescent athletes aged 9 to 18 years old. The number of trials in each studies were three in four studies and four trials in one study. Most of the subjects were healthy athletes with no existing lower extremity injury that could alter the balance. Most of the studies resulted in reliable balance assessment tools. Further information about characteristics of the studies can be seen in Table 1.

3.2. Y-Balance Test

The Y-Balance test was found in three studies by Smith et al (2018), Greenberg et al (2019), and Linek et al (2017). The ICC showed good to excellent intrarater reliability (range from 0.63 to 0.998) from the three studies. All the studies used the Y-Balance Test protocol by Plisky et al (2009). The subject in the study by Smith et al (2018) are 110 male and female high school athletes, 25 female multisport athletes in Greenberg et al (2019), and 38 male football athletes in Linek et al (2017). The number of trials are three in all studies.

3.3. Dual Task Postural Control Testing

Dual task postural control testing was found in a study by Campolettano et al (2020). The ICC of the study showed good to excellent intrarater reliability (>0.7). The subjects were nine youth male athletes without any active involvement in a contact sport during the study period. There were four identical testing sessions spaced a week apart.

3.4. Tandem Gait Test

Tandem gait test was found in a study by Howell et al (2019). The intrarater reliability was high both for single task (ICC = 0.95) and dual task (ICC = 0.98). The subjects were 32 young female and male athletes with three testing sessions.

3.5. Quality Appraisal of Reliability Study (QAREL) Assessment

There were total five studies that reviewed for QAREL assessment. The percentage of Yes were 44.4%, 87.5%, 62.5% in two studies, and 60% for Smith et al, Greenberg et al, Howell et al, Campolettano et al, and Linek et al, respectively. The blinding information were mostly unclear or not available, both the raters and subject blinding, but the samples' representativity and statistical analysis was well informed. The highest percentage of Yes was in a study by Greenberg et al (2019), while the lowest percentage of Yes was in a study by Smith et al. Both of the studies by Greenberg and Smith were testing the reliability of the Y-Balance test. Despite of both studies assessed the reliability of the same balance measurement tool with the same protocol, the study by Smith et al provide less detailed information compared with the study by Greenberg et al which could alter the outcome of the QAREL scale.

Figure 1: PRISMA flowchart for articles selection process

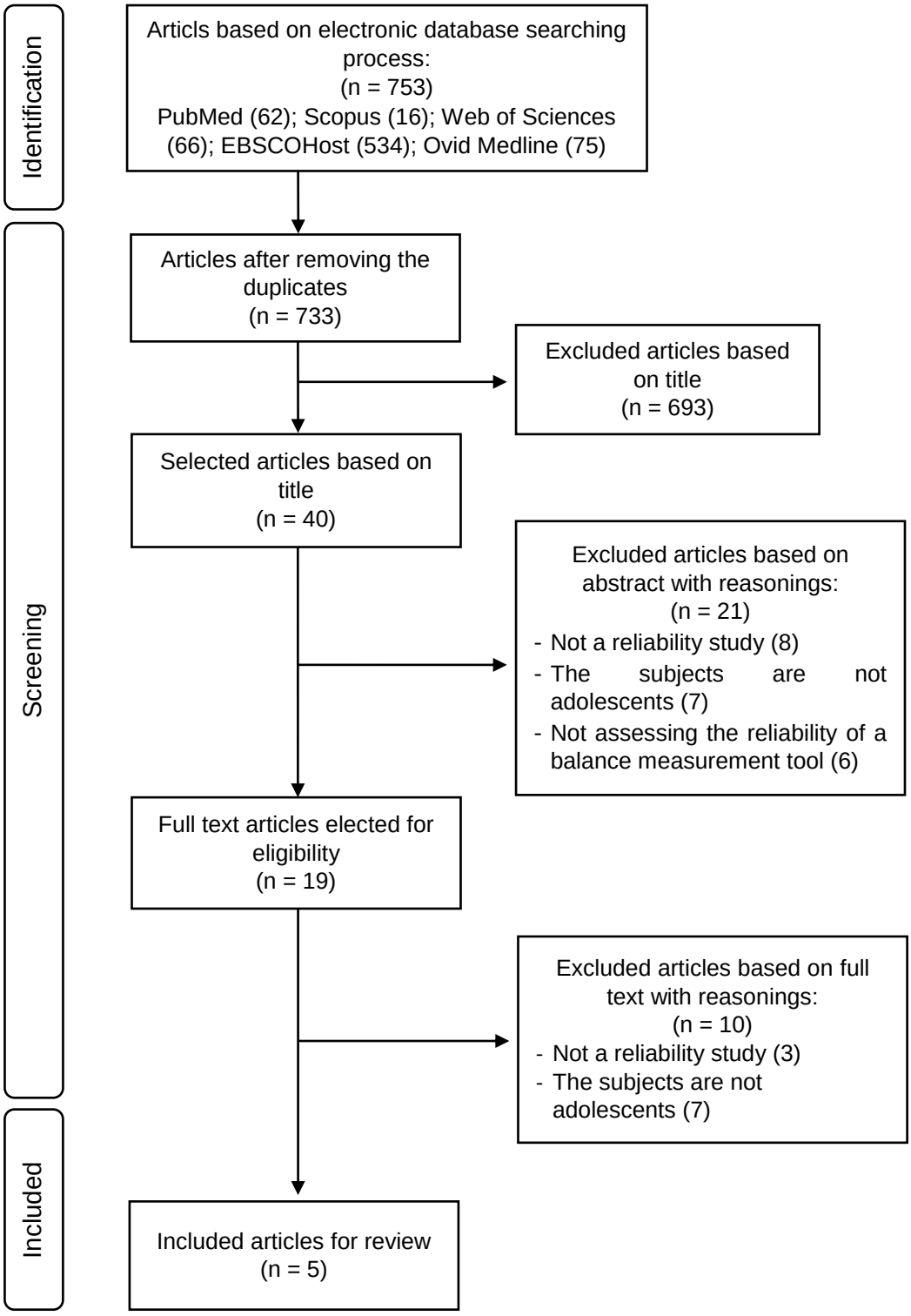

Table 1: Characteristic of Studies

Author (year)	Objective	Participants (gender/age)	Measurement technique	Number of trials	Reliability	
					Interpretation	Result
Smith et al (2018)	1) to characterize the prevalence of YBT-LQ asymmetries and performance in a cross-sectional sample of adolescents, 2) to examine possible differences in performance on the YBT-LQ between male and female adolescents, and 3) to describe the test-retest reliability of the YBT-LQ in a subsample of adolescents.	110 high school athletes (51 male, 59 female/13-18 y.o)	Y-Balance Test™ Lower Quarter (YBT-LQ)	3	Good to moderate intrarater reliability	Test-retest reliability for the ANT reach direction was the highest (ICC2,1 = 0.89), followed by the PL (ICC2,1 = 0.76) and PM (ICC2,1 = 0.63) directions, respectively.
Greenberg et al (2019)	To estimate the interrater and test-retest (intrarater) reliability of the Y-Balance Test in a group of early adolescent females	25 multisport adolescent athletes (female/12-14 y.o)	Y-Balance Test	3	Good to excellent interrater reliability Moderate to excellent intra-rater reliability	Day 1 values were excellent for the all-reach directions and COMP scores of the right limb (ICC 0.973-0.992) and left limb (ICC 0.960-0.989) except for the left ANT reach which was good (ICC 0.811). For day 2, interrater reliability of YBT scores were excellent for all reach directions and COMP scores of the right limb (ICC 0.988-0.998) and left limb (ICC

						0.993-0.999). Testretest (intrarater) reliability of YBT scores were moderate to excellent right limb (ICC PM 0.681- ANT 0.908) and moderate to good for left limb (ICC PL 0.714 - ANT 0.811).
Howell et al (2019)	Examine test-retest reliability of the single task and dual task tandem gait test among healthy young athletes	32 healthy atheltes (9-18 yo/M16F16)	single task and dual task tandem gait test	3	High intra-rater reliability	The intrarater reliability among trials was high for single task (ICC [3,1] = 0.95) and dual task (ICC [3,1] = 0.98)
Campolettano et al (2020)	Investigate the reliability of a cognitive dual task postural control testing protocol	9 youth athletes (M=9/11.6±0.5 yo)	dual task postural control testing	4	Good to excellent intra-rater reliability	The eyes closed, no task test condition was associated with good or excellent test retest reliability (ICC > 0.7) for each of five measures
Linek et al (2017)	To asses the reliability of the YBT in adolescent athletes, as well as to estimate the necessary number of trials to stabilize the YBT result.	38 athlete (mean 15.6 years)	Y-Balance Test	3	Good to excellent intra-rater reliability	The intraclass correlation coefficient (ICC3,1) for the three attempts ranged from 0.57 to 0.82

***YBT-LQ**=Y-Balance Test-Lower Quarter; **ANT**=anterior; **ICC**=intraclass correlation coefficient; **PL**=posterolateral; **PM**=posteromedial; **COMP**=composite; **YBT**=Y-Balance Test*

Table 2: QAREL Assessment Result

Questions	Smith et al (2018)	Greenberg et al (2019)	Howell et al (2019)	Campolettano et al (2020)	Linek et al (2017)
Was the sample of subjects representative?	Yes	Yes	Yes	Yes	Yes
Was the sample of raters representative?	Unclear	Yes	Unclear	N/A	Yes
Were raters blinded to the findings of other raters?	Unclear	Yes	N/A	N/A	Yes
Were raters blinded to their own prior findings?	Unclear	Yes	Unclear	Unclear	Unclear
Were raters blinded to the accepted reference standard?	Unclear	N/A	N/A	N/A	Unclear
Were raters blinded to clinical information that was not part of testing procedure?	N/A	N/A	N/A	Unclear	Yes
Were raters blinded to additional non-clinical cues?	N/A	N/A	N/A	Unclear	N/A
Was the order of examination varied?	Unclear	Unclear	Yes	Yes	Unclear
Was the time interval between repeated masure appropriate?	Yes	Yes	Yes	Yes	Unclear
Was the test applied correctly and interpreted appropriately?	Yes	Yes	Yes	Yes	Yes
Were appropriate statistical measures of agreement used?	Yes	Yes	Yes	Yes	Yes
Percentage of Yes	**4/9 = 44.4%**	**7/8 = 87.5%**	**5/8 = 62.5%**	**5/8 = 62.5%**	**6/10 = 60%**

4. Discussion

Based on the authors' opinion, balance is one of the most crucial aspects of performance for adolescent athletes because they have much potential for their future athlete careers. With balance as a vital performance component in an athlete, balance also became a factor in line with the risk of injury.

Balance is an important aspect that needs to be considered for athletes. The changes of anatomic and physiological in adolescence could affect postural control ability. Poor postural control or balance is associated with a higher risk of sports-related injury [6]. Therefore, a reliable balance assessment instrument may play an essential role for clinicians in identifying individuals, especially athletes, at higher risk of injury or determining the functional capacity following injury [2].

After searching from five electronic databases that resulted in 753 studies based on screening, five studies met the eligibility criteria. The included studies assessed the reliability of the balance measurement instruments in adolescent athletes aged 9 to 19 without any existing lower extremity injury or other condition that may alter the balance function. Three balance measurement instruments were found, such as the Y-Balance Test in three studies, Tandem Gait Test, and Dual-Task Postural Control Testing in other studies. Most of the studies used various kinds of athletes that did not specify what kind of sport the athletes did. Apart from depicting a wide variety of subjects in the included studies, they used a precise measure of reliability.

From the measurement tools mentioned, it can be distinguished the type of balance assessed. The Y-Balance Test and Tandem Gait Test were used to measure balance dynamically. The Dual-Task Postural Control was used to measure balance statically by implementing sensory activity in the body[14]. The Y-Balance Test was found in three included studies by Smith et al. (2018), Greenberg et al. (2019), and Linek (2017) using the Y-Balance Instrument Kit with a protocol by Plisky et al. (2009). The instrument technique used to measure dual-task postural control in a study by Campolettano (2020) used a computer screen and plate as a marker of the centre of pressure (COP). All of the included studies have good to excellent reliability based on the statistical result of each balance assessment instrument (ICC > 0.66).

However, the finding of this study shows a high percentage of Yes in the QAREL assessment (87.5%) in the reliability study by Greenberg et al. (2019), which used the Y-Balance Test. The most reliable balance assessment tool based on the QAREL scale is the Y-Balance Test from the study by Greenberg et al. (2019). The high QAREL score of this study was supported by some points, such as the samples representing the population well. Besides, the raters were also blinded to each other's findings and previous findings, compared with the Smith study, which was not clearly explaining the blinding. Moreover, in another aspect of this study, it is explained that there is a difference in the assessment results on day one and day two, where on day one, the composite value on the measurement is 2.31%. On day two, the composite value of the measurement is 2.57%, and in the study conducted by Smith et al. (2018), it is not clearly explained. In addition, in the study conducted by Greenberg, some evaluators were blinded to their prior finding aspect, which in other studies was not explained at that point.

4.1. Summary Result

The result showed that the Y-Balance test is the most reliable balance assessment instrument[2], with a QAREL score of 87.5%. The interrater reliability was excellent for all reach directions, and there was no significant difference between the right and left lower limbs. Early evidence by Cameron (2019) reviewed the inter-rater and intra-rater reliability of the SEBT/YBT. The high-level evidence showed excellent intra-rater and inter-rater reliability of SEBT/ YBT for dynamic balance measurement.

4.2. Implication

The results of this review show that body position does not affect the data results from the Y-Balance Test. It is inversely proportional to other measuring tools, such as tandem gait and postural control measurements, where body position can

significantly impact the assessment data. Therefore, in implementing the Y-Balance Test, it is necessary to normalize the leg length data to allow comparisons between patients so that the Y-Balance Test can be used as an accurate measuring tool for dynamic balance with appropriate results between several raters[8].

5. Conclusions

The results of this systematic review demonstrate some reliable balance measurement tools for the adolescent athletes population, including the Y-Balance test, Dual Task Postural Control Testing, and Tandem Gait Test. After extracting the data and assessing the quality of the studies using the QAREL scale, it was found that a study by Greenberg et al. (2019) assessing the reliability of the Y-Balance test showed the highest percentage of Yes, up to 87.5%. Hence, this systematic review of the reliability study found that the Y-Balance Test is the most reliable instrument for assessing balance in healthy adolescent athletes.

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