HUMAN MOVEMENT (ISSN 1899-1955)
2023; 24(3): 78–84

Testing dynamic balance in youth female volleyball players: development, reliability, and usefulness

original paper
DOI: https://doi.org/10.5114/hm.2023.116635

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ABSTRACT

Purpose. The aim of this research was to develop a dynamic balance test and examine its reliability by comparing first trial results with the average and best ones from multiple attempts.

Methods. Overall, 32 volleyball players (aged 11.3 ± 0.67 years) were investigated in 2 sessions (with a 14-day interval), each consisting of 3 trials of the modified bench walk with 3 turns (MBW3T) test. Three test methods were compared: first trial ($MBW3T_{trial1}$), average result ($MBW3T_{mean}$), and best result ($MBW3T_{best}$). A paired-sample *t*-test determined differences with an effect size. Test-retest reliability was assessed with an intraclass correlation coefficient.

Results. The paired-sample *t*-test revealed no significant difference in performance between test and retest for $MBW3T_{trial1}$ ($t = 0.01$, $p = 0.99$), $MBW3T_{mean}$ ($t = -0.46$, $p = 0.65$), and $MBW3T_{best}$ ($t = -1.05$, $p = 0.30$). Standard error of measurement (SEM) as the absolute reliability within-individual variation parameter showed that $MBW3T_{trial1}$ had higher variation than $MBW3T_{mean}$ and $MBW3T_{best}$, in which the measurement error was minimal. To identify usefulness, we calculated the smallest worthwhile change and compared it with SEM for different effect sizes; the test was rated marginal to satisfactory. The study results indicated fair reliability when the first trial was observed and good reliability for the mean and best of 3 trials.

Conclusions. $MBW3T_{mean}$ and $MBW3T_{best}$ are cheap, simple, reliable, and marginal to satisfactory useful measures for assessing dynamic balance in youth female volleyball players and can be used in scientific and practical settings.

Key words: coordination, team sports, adolescent, athletic performance, movement

Introduction

Motor coordination appears to be crucial for success in different sports dominated by different movement structures, such as gymnastics [1], judo [2], or volleyball [3]. Although it is fundamental to performance development in sport, there is an evident lack of consensus between researchers on the theoretical structure of motor coordination abilities and reliable and valid procedures of testing them [3]. On the other hand, the majority of authors consider dynamic balance to be an important part of motor coordination and consequently involve it in testing protocols [1, 4]. Balance is an ability to maintain postural stability of the body without support throughout the somatosensory, vestibular, and visual systems as a feedback from the central nervous system [5]. Furthermore, there is a classification into static balance ability, when the body is in a stationary position, not intended to move, and dynamic balance ability, when the body is in active movement, trying to maintain balance [6].

Balance is important for children who want to be engaged in sports activities because maintaining controlled body movement is essential for athletes during competitions and training [7, 8]. Elite players in team sports games are supposed to possess optimal balance control in static and, especially, dynamic conditions, as well as the ability to move in a controlled way over the limited playing surface [9]. Good balance reduces the risk of injury in every period in life [10, 11]. Therefore, incorporating balance training into the program has a positive impact on many aspects of sports performance [12].

In numerous studies one can find different protocols for testing static and dynamic balance in the athlete population, e.g. the Balance Error Scoring System (BESS).

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Received: September 29, 2021
Accepted for publication: June 4, 2022

Citation: Đolo K, Grgantov Z, Jelaska I. Testing dynamic balance in youth female volleyball players: development, reliability, and usefulness. Hum Mov. 2023;24(3):78–84; doi: https://doi.org/10.5114/hm.2023.116635.

BESS was designed to easily assess postural stability in athletes who are at high risk of contusion, with an intraclass correlation coefficient (ICC) of 0.90. Despite a high reliability due to the BESS subcategories, the test is rated as inadequate for assessing postural stability [13]. The Star Excursion Balance Test and the Y Balance Test are also tools for assessing lower extremity balance and they are applied after the implementation of a rehabilitation program. Both tests have excellent inter-rater reliability (0.88–0.96) and therefore they can be applied in a healthy population [14]. Another test, the Motor Control Test, in most cases has been tested among older adults, with a high reliability of 0.85 [15]. All previously mentioned tests are utilized in computerized dynamic posturography [16], although very reliable tests are not 'similar' to situational movement (lack of ecological validity). It is important to underline that movement structures in such tests are in general not dynamic enough owing to the lack of demands on the proprioceptive and the somatosensory systems, especially those which influence the reestablishment of posture after a perturbation [17, 18].

Consequently, for an ecologically valid estimation of dynamic balance among youth team sport athletes, tests with more pronounced dynamic components should be developed and examined with reference to reliability and usefulness. For example, more dynamic tests should be used, such as the Backward Balance Test, drawn from the Körperkoordinationstest für Kinder battery of tests, or bench walk with 3 turns [4]. The Backward Balance Test has recently been researched for test-retest reliability (0.80–0.95) [19]. There is, however, an evident lack of current investigations on the reliability and usefulness of bench walk with 3 turns. Furthermore, the performing complexity of this test clearly indicates a need for its modification; among others, it should be made more volleyball-specific and easier to apply in young players or children.

In addition, the assessment of the first trial, the average result, and the best result of 3 trials have been used as outcome scores [20, 21]. Owing to lack of time or general resources, some coaches either do not conduct testing at all or implement tests in such a manner that only one item is performed for each test. Therefore, that single item would be the first one in our case; it was compared with the 2 methods recommended by scientists, i.e. the average result of multiple attempts and the best result of multiple attempts.

This testing procedure gives a more complete estimation of reliability and usefulness, especially respecting the fact that inter-trial variability is greater in children [22]. Following the previously stated facts, this study aimed to fill the existing gap – to modify the dynamic balance ability test in youth female volleyball players so that it more precisely simulated volleyball-specific situations. It was hypothesized that the test would present good reliability and potential usefulness to assess balance in a sample of young volleyball players.

Finally, the aim of this research was to develop a dynamic balance test and examine its reliability by comparing first trial results with the average and best ones from multiple attempts.

Material and methods

Study design

Owing to the issue of finding the most suitable balance test for youth female volleyball players, this research analysed the reliability and usefulness of the modified (i.e. ecologically more valid) dynamic balance test by comparing the first, average, and best results.

Participants

A sample of 36 youth female volleyball players were recruited from 3 randomly chosen clubs in Herzegovina; they represented the same level of training and competition. During interviews with players, the participation criteria were verified: the inclusion criterion of at least 6 months of training experience and the exclusion criterion of any kind of injury that would prevent the athletes from testing. Two participants were excluded from the sample because of the recent injuries. Furthermore, the subjects were asked to identify their health status; then, another 2 participants were removed from the sample because of a musculoskeletal disorder and recent musculoskeletal injuries. Finally, a convenience sample of 32 participants (age: 11.3 ± 0.67 years, training experience: 6–48 months) completed both testing sessions. At the time of testing, they had 2–3 workouts per week. The parents of all participants were informed in detail on the goal of the research and testing procedures; they were notified that any player could withdraw from the testing at any time with no consequence.

Procedures

The test was performed on an indoor floor surface to control for the environmental conditions. The hall temperature was ca. 25°C and humidity equalled 65%. A dynamic warm-up was conducted before the testing and included 4 minutes of jogging and 6 minutes

of head, shoulder, hip, and knee mobility exercises. One experienced measurer, the first author of the study, evaluated all participants. Before the testing, the procedure was precisely demonstrated to all subjects. After one preparatory attempt, the individuals performed the test 3 times, with a 30-second pause between the trials. The assessment was organized in 2 testing sessions, with a 14-day break between them. Each session was carried out in the afternoon, between 1:00 and 4:00 p.m. The participants were dressed in shorts and T-shirts.

Bench walk with 3 turns test

To evaluate the volleyball players' coordination, we used the modified bench walk with 3 turns (MBW3T) test (dynamic balance), in which the participant stands behind a 3-m long bench [23]. Before the signal is provided, child has right leg on the bench. At a signal, the child stands on the bench and tries to walk to the other end, while making three 360° turns (Figure 1). If the examinee loses their balance, they can touch the ground up to 2 times; each touch represents one negative second added to the final measured time or, otherwise, becomes a reason for the test to be repeated. The final score is gathered as the time from the starting signal to the touch of the ground behind the bench. The modification of the test consisted in the fact that the bench was not turned upside down, and the movement was performed on the wide side (22 cm), which is 12 cm wider than the narrow one. Consequently, the test would not be too complicated and the movements with turns would be even faster and more dynamic, which is specific for volleyball.

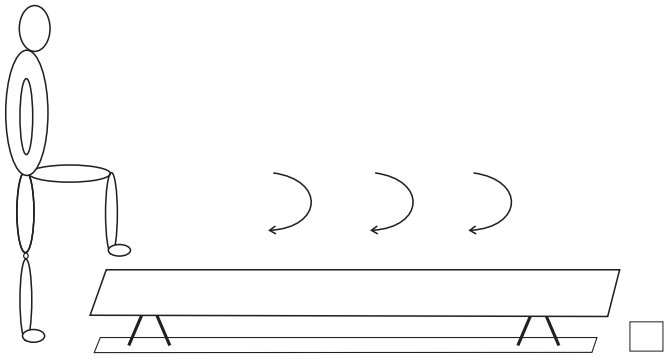

Figure 1. Visual representation of the modified bench walk with 3 turns test

Statistical analysis

All data were analysed with the SPSS Statistics 27.0 for Windows and GraphPad Prism 9 (GraphPad Software, Inc.) software and are presented as mean and standard deviation. The Kolmogorov-Smirnov test was used to verify the normality of the data. Components of reliability such as systematic bias, within-individual variation, and retest correlation were calculated [24].

A paired-sample *t*-test was conducted to determine if there were the significant differences (systematic bias) between the 2 testing occasions (test-retest). In addition, the effect size was calculated in accordance with Cohen's *d*. The effect sizes were interpreted as follows: 0.0 to < 0.2, trivial; 0.2 to < 0.6, small; 0.6 to < 1.2, medium; 1.2 to < 2.0, large; 2.0 to < 4.0, very large; and ≥ 4.0, extremely large [25]. Test-retest reliability was assessed by using ICC model alpha with a 2-way mixed effect and a 95% confidence interval (CI) when analysing the first trial, the average result, and the best result [26]. ICCs are considered excellent if larger than 0.75, good from 0.60 to 0.74, fair from 0.40 to 0.59, and poor if ≤ 0.39 [27]. Furthermore, to identify within-individual variation and the 95% CI over the repeated trials, the standard error of measurement (SEM) was determined by using the following formula:

$$SEM = SD \cdot \sqrt{1 - ICC}$$

Similarly, to identify the 95% CI of changes in scores which were generated by a real change in score and not by the error in measurement, minimal detectable change (MDC) was calculated with the following formula:

$$MDC = SEM \times 1.96\ \sqrt{2}$$

The coefficient of variation (CV) expressed as the percentage of the mean score and CV% below 10% were considered acceptable [28]. The smallest worthwhile change (SWC) was also calculated for various effect sizes (0.2, 0.6, and 1.2 multiplied by the between-participant standard deviation) to verify the usefulness of the test. The usefulness of the test was assessed by analysing SWC and SEM, where SEM below SWC indicated good usefulness, SEM similar to SWC was rated satisfactory, and SEM higher than SWC was considered as marginal [29].

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Re-

search Ethics Committee of the Faculty of Kinesiology, University of Split, Croatia (approval No.: 2181-205-02-05-18-002 as of January 8, 2018).

Informed consent

Informed consent has been obtained from all individuals included in this study and their parents.

Results

The sensitivity of the tests was monitored with the Kolmogorov-Smirnov test, which revealed no significant difference between the obtained distribution results and normal distribution ($p > 0.20$, skewness = 0.15, kurtosis = –0.11). The results of the paired-sample *t*-test demonstrated no significant difference in performance between test and retest for $MBW3T_{trial1}$ ($t = 0.01$, $p = 0.99$), $MBW3T_{mean}$ ($t = -0.46$, $p = 0.65$), and $MBW3T_{best}$ ($t = -1.05$, $p = 0.30$). High individual consistency in results between the 2 testing sessions (Table 1) was observed for all 3 testing responses (Figures 2–4).

Table 1. Performance responses during test and retest of MBW3T

Variable (s)	Test	Retest	*ES* (95% CI)
$MBW3T_{trial1}$	7.30 (1.57)	7.30 (1.42)	0.00 (–0.34 to 0.35)
$MBW3T_{mean}$	7.21 (1.20)	7.32 (1.42)	–0.08 (–0.43 to 0.27)
$MBW3T_{best}$	6.39 (1.00)	6.59 (1.31)	–0.18 (–0.53 to 0.17)

Values are presented as mean and standard deviation. MBW3T – modified bench walk with 3 turns ($MBW3T_{trial1}$ – first trial, $MBW3T_{mean}$ – mean of 3 trials, $MBW3T_{best}$ – best of 3 trials), *ES* – effect size

Furthermore, the relative reliability assessment together with 95% CI and absolute reliability parameters of the MBW3T test are presented in Table 2. The test-retest reliability indicates a fair value at the first trial, while when it comes to mean and best results, the reliability was good. SEM was investigated as an absolute reliability within-individual variation parameter. It can be observed that $MBW3T_{trial1}$ exhibited

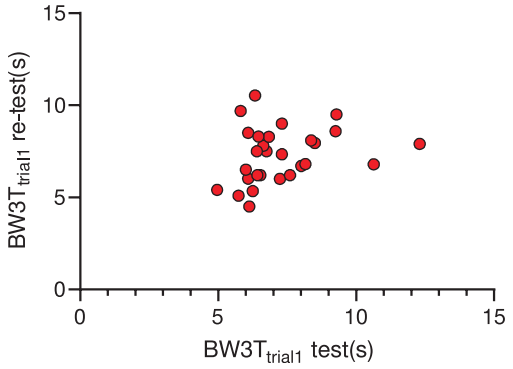

Figure 2. Scatterplot of the first trial results of the modified bench walk with 3 turns (BW3T) during test and retest

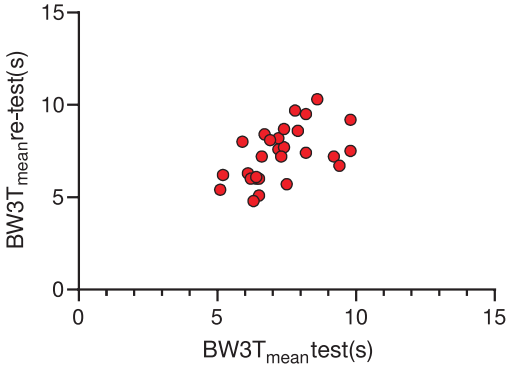

Figure 3. Scatterplot of the mean results of 3 trials of the modified bench walk with 3 turns (BW3T) during test and retest

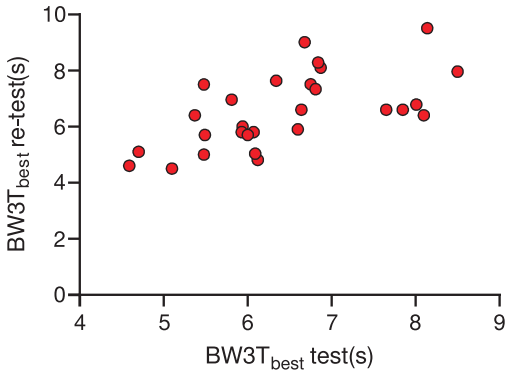

Figure 4. Scatterplot of the best results of 3 trials of the modified bench walk with 3 turns (BW3T) during test and retest

Table 2. Measures of reliability and usefulness of performance variables of MBW3T

Variable (s)	ICC (95% CI)	*p* (ICC)	SEM (95% CI)	SWC (0.2, 0.6, and 1.2)	CV%	MDC
$MBW3T_{trial1}$	0.47 (–0.12 to 0.74)	0.05	5.99 (4.80–7.96)	1.7, 5.1, 10.2	6.27	16.55
$MBW3T_{mean}$	0.68 (0.38–0.84)	< 0.01	2.38 (1.88–3.24)	0.68, 2.04, 4.08	3.40	6.58
$MBW3T_{best}$	0.73 (0.45–0.87)	< 0.01	0.77 (0.62–1.03)	0.22, 0.66, 1.32	1.10	2.13

MBW3T – modified bench walk with 3 turns ($MBW3T_{trial1}$ – first trial, $MBW3T_{mean}$ – mean of 3 trials, $MBW3T_{best}$ – best of 3 trials), ICC – intraclass correlation coefficient, SEM – standard error of measurement, SWC – smallest worthwhile change, CV% – typical error expressed as coefficient of variation, MDC – minimal detectable change

higher variations compared with $MBW3T_{mean}$ and $MBW3T_{best}$.

In the first place, SEM was tested as the absolute reliability within-individual variation parameter and it was shown that $MBW3T_{trial1}$ presented higher variation (6.27%) than the $MBW3T_{mean}$ and $MBW3T_{best}$ results. To identify a meaningful change in performance, we calculated SWC by multiplying standard deviation by 0.2, 0.6, and 1.2, finding that SEM was higher than SWC for variables that were multiplied by 0.2 and 0.6.

Discussion

This study aimed to modify the bench walk with 3 turns test so that the ecological validity was even more emphasized, as well as to examine the reliability and usefulness of this test. In doing so, the existing testing procedure was modified in a way that the movement was performed on the wide side of a bench so the test performance was faster, more dynamic, and therefore more volleyball-specific. After all, it has to be underlined that a very limited number of studies deal with dynamic balance issues in volleyball so the results of this research are found to be hard to compare with previous outcomes. The test-retest reliability was observed through ICC and the results of $MBW3T_{mean}$ and $MBW3T_{best}$ showed good reliability. It can be concluded that both approaches are useful in the assessment of balance ability. The MBW3T test included reactions to postural disturbances evoked by abduction-adduction movements (i.e. turning around). Consequently, the application of more difficult tasks and posturokinetic activities leads to larger errors, which is an age-dependent process [30]. If MBW3T was implemented in a population of volleyball beginners (i.e. children), the number of turns should probably be reduced and reliability would increase. When dealing with younger age categories, one has to take into account that at the age of 12, dynamic balance, along with spatial orientation and rhythmic capacity, are the most frequently dominating abilities in volleyball [31]. Furthermore, at the age of 15, volleyball players show the best results in dynamic balance. Considering the previously stated facts, one can conclude that there is a possibility to obtain higher reliability indexes in an observed sample. Also, in the context of junior and senior age categories and the interaction of their coordination capacities with long-term training processes, it would be of interest to examine reliability indexes in that population [23, 32].

Moreover, the SEM values, as an estimate of the measurement error, indicate that the typical score in $MBW3T_{mean}$ and $MBW3T_{best}$ variables can deviate by 2.38 to 0.77 seconds. Additionally, SEM is used to calculate MDC [33]. When observing MDC, it is important to monitor progress, in this case, of volleyball players so that intra-trial variations do not inaccurately suggest a change [31]. In this research, random error was found to be low, which is reflected in good reliability.

The usefulness of the test was examined by comparing the results of $SWC_{(0.2,\ 0.6,\ and\ 1.2)}$ with SEM. It can be concluded that the test can be utilized to detect changes that exceed 0.6–1.2 times the test standard deviation [29]. $SWC_{(0.2)}$ showed marginal usefulness and $SWC_{(0.6)}$ presented a satisfactory level of usefulness of the test. It should be noticed that poorer results in $MBW3T_{trial1}$, with low reliability and usefulness, can be of great importance for practitioners. With this in mind, one should not conduct fewer than 3 testing trials so that conclusions can be drawn by using the mean or best result of 3 trials because they are equally reliable [34]. The modification of the test was introduced to make the performance level adjustable for the children and it has shown to be a reliable measure. Also, the test modification is reflected in the dynamic aspect as volleyball is among the most dynamic sports [35]. The dynamic balance performance would have probably been even better if the participants had applied positive self-talk during the task as a motivation strategy [36]. It would have been more effective if the measurer had motivated the children with a precisely defined positive talk before their performance.

This research had some limitations. First of all, the study involved a relatively small sample size – it is unknown if a larger sample size would have brought about similar results. The second limitation is the fact that aspects of validity were not analysed. Moreover, in future research, the test would be even more dynamic if the number of turns is to be reduced. Most studies focus on the clinical application of balance and less on athletes, and the vast majority of them are based on computerized dynamic posturography. Consequently, another limitation refers to the impossibility of comparison with other, similar studies. Additionally, only female athletes were tested, which limits referring the results to male athletes.

In practice, balance tests are in most cases expensive to perform. This study indicates reliability of a dynamic balance test that is simple and inexpensive and therefore can be applied in all sports, not only volleyball.

Conclusions

Testing balance ability in children with the MBW3T test revealed a good level of test-retest reliability for 2 testing procedures (mean and best results). These findings indicate that there is a need to perform more than one trial for the test to be reliable. Nevertheless, the study proves that MBW3T can be considered as a cheap, reliable, and satisfying tool for dynamic balance estimation and can be used in scientific and practical settings, especially in coordination monitoring in longitudinal research designs.

Acknowledgements

We wish to thank the children who participated in the study, their parents, and trainers in schools.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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