DOI 10.26773/smj.240219

SportMont

REVIEW PAPER

The Upper Quarter Y-Balance Test: A Scoping Review of Reference Values, Reliability, Determinants, and Practical Application

Tjaša Ribnikar[1], Anja Maguša[1], Žiga Kozinc[1,2]

[1]University of Primorska, Faculty of Health Sciences, Polje 42, SI-6310 Izola, Slovenia, [2]University of Primorska, Andrej Marušič Institute, Muzejski trg 2, SI-6000 Koper, Slovenia

Abstract

The aim of this scoping review was to comprehensively examine the Upper Quarter Y-Balance Test (UQYBT), including reference values, reliability, determinants, and its practical application. By including studies irrespective of publication date, participant demographics, or research purpose, provided they were in English and incorporated UQYBT as a primary or secondary variable, an extensive dataset was collected. The focus was on limb-length-normalized results to establish standardized reference metrics. Reliability studies highlighted the UQYBT's consistency across sessions and raters. The application of UQYBT to assess injury risk is questionable. Studies assessing its relationship with sports performance have also yielded varying results. UQYBT seems to be sensitive to various exercise based-interventions, as shown by several clinical trials. This review furnishes practitioners and clinicians with valuable insights for the application of UQYBT in sports and healthcare settings.

Keywords: *injury prevention, athletic performance, reference values, scoping review, upper limb*

Introduction

Postural balance, the ability of maintaining the body's centre of mass directly over its base of support, is pivotal in everyday life. It ensures the smooth execution of daily tasks and is also vital in sports. Proficient balance not only correlates with some aspects of sports performance (Hrysomallis, 2011), but may also offer protection against injuries (Hrysomallis, 2007; Gribble et al., 2012). Hence, in sports practice, balance assessment is of utmost importance. While sophisticated laboratory methods like tracking the centre-of-pressure movement using force plates have been commonly applied to athletes (Kiers et al., 2013; Trajković et al., 2021; Zemková, 2022), the practicalities and costs often make them less feasible for routine evaluations. In light of these constraints, previous researchers have investigated the reliability, validity and practical application of several field-based balance test alternatives (Sabchuk et al., 2012; Bhat & Moiz, 2013; Clarke et al., 2019; Velarde-Sotres et al., 2021). Star-excursion balance test, and its simplified adaptation, the lower-quarter Y-balance test, have been commonly applied to test lower-limb dynamic postural balance in athletes (Plisky et al., 2009; Gribble et al., 2012; Bhat & Moiz, 2013; Powden et al., 2019). However, tests for upper body postural balance and stability have not been as extensively studied.

Early attempts to establish a practically useful field-based test for upper body included The One-Arm Hop Test (Falsone et al., 2002) and The Closed-Kinetic Chain Upper Extremity Stability Test (Goldbeck & Davies, 2000). However, while requiring balance ability, these tests do not challenge the subject to the limits of stability, which motivated the development a new version of Y-balance test for upper body, also known as The Upper Quarter Y-Balance Test (UQYBT) (Gorman et al., 2012). Based on previous evidence on reliability and practical application of Y-test for lower limbs (Plisky et al., 2009; Coughlan et al., 2012), the researchers suggested that UQYBT could provide useful information about upper body balance and stability (Gorman et al., 2012; Westrick et

Correspondence:

Žiga Kozinc
Universiry of Primorska, Faculty of Health Sciences, SI-6310 Izola, Slovenia
E-mail: ziga.kozinc@fvz.upr.si

al., 2012) and shoulder function (Hegedus et al., 2014). The UQYBT requires stability on the supporting arm and mobility of the thoracic spine by reaching the arm in the medial, inferolateral and superolateral directions during a push-up position. The inferolateral and superolateral are positioned at an angle of 135 degrees to the medial direction and there is 90 degrees between them. Executing a reach in each direction necessitates a combination of trunk stabilization, thoracic spine rotation, and scapular mobility and stability. Therefore, it evaluates an individual's balance, proprioception, strength, and range of motion. It can also provide an asymmetry index between the two sides (Gorman et al., 2012). Before undertaking the UQYBT, it is necessary to measure the arm's length in a standing position, shoulder in 90 degrees of abduction and elbow extended. The measurement is taken from the C7 spinous process to the tip of the middle finger (Gorman et al., 2012; Westrick et al., 2012). The test is first conducted on the non-dominant side, followed by the dominant side. The dominant side is determined by the arm used for throwing. The participant starts in a push-up position, with feet shoulder-width apart and supported by one arm. The tested arm first reaches in the medial direction, followed by IL, and finally SL. After each reach, the participant returns to the starting position. Initially, two familiarization repetitions are carried out. Subsequently, the participant performs three repetitions, taking a 30-second break between each. If the participant struggles to maintain balance in the push-up position or leans excessively on the board (used to measure reach distance), the test must be redone. Ultimately, the reach value for each direction is calculated and normalized to limb length (Gorman et al., 2012; Westrick et al., 2012). The composite score may be calculated as normalised mean of the three reach directions (Borms & Cools, 2018). Figure 1 shows the performance of UQYBT in all three directions.

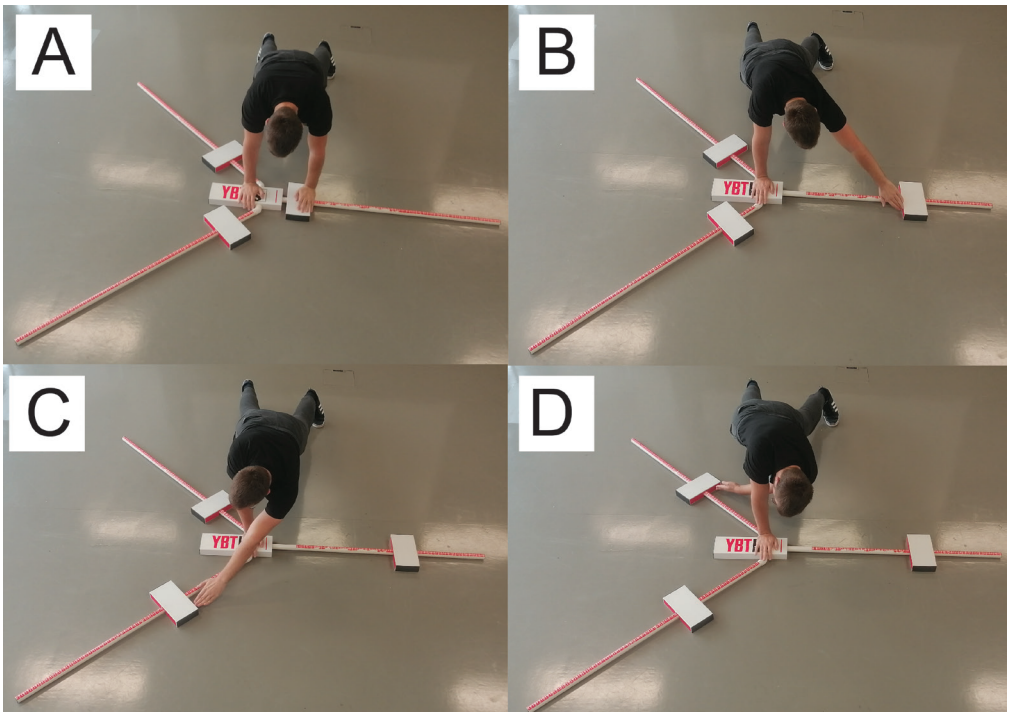

FIGURE 1. A display of performance of the UQYBT test. A – initial position; B – medial reach; C – superolateral reach; D – inferolateral reach.

Initial studies have already reported good to excellent intra-visit reliability for UQYBT in general population, with intra-class correlation coefficient (ICC) in range of 0.80 to 0.99. The highest intra-visit test-retest reliability was for the superolateral direction (ICC=0.92-0.99) and the lowest for the medial direction (ICC=0.80-0.96). Inter-rater reliability was perfect (ICC=1.0) (Gorman et al., 2012). Subsequent studies have also confirmed the excellent reliability in athletes (ICC=0.92-0.97) (Borms et al., 2016). Early studies showed a very low correlation with The Closed-Kinetic Chain Upper Extremity Stability Test (Taylor et al., 2016), suggesting the two tests yield different information on upper body postural stability and balance. Therefore, the UQYBT appears to be a reliable and potentially useful test. Based on a Delphi study involving 22 experts from sport science and medicine with an extensive knowledge of upper limb functional testing, UQYBT mainly assesses the stability of the gleno-humeral joint and the stability of the upper arm kinetic chain. The experts also highlighted that it is inexpensive and involves both the shoulder and the trunk They thought that it may be used for closed chain sports (e.g., wrestling), but not for open chain sports (e.g., volleyball) (Tooth et al., 2022).

Although the star-excursion balance test and the Y-balance test for the lower limbs have been subjects of past literature reviews (Gribble et al., 2012; Powden et al., 2019), there has yet to be a review on the UQYBT. Therefore, the aim of this article is to compile all existing research on the UQYBT. This will provide reference values for various age groups and sports and will examine the test's reliability, its correlation with other assessments, and its capability to identify injury risk. Understanding the intricacies and practical applications of the UQYBT is vital for clinicians, trainers, and sports professionals. A comprehensive review of the UQYBT can offer insights into its effectiveness as a diagnostic tool and its potential impact on training and rehabilitation strategies. By establishing reference values and examining its reliability, sports profes-

sionals can make informed decisions about athlete performance and injury prevention. Furthermore, this review aims to identify research gaps and areas that require further exploration, thereby motivating subsequent studies to expand our understanding of the UQYBT. As exercise science and sports medicine continues to evolve, staying updated with the latest assessment techniques and their implications is paramount. By pinpointing areas of uncharted territory in UQYBT research, the aim is to guide future investigations, ultimately advancing the field and enhancing athlete care and performance.

Methods

A scoping review was conducted to map the extent and range of literature related to the UQYBT and to identify key concepts, gaps in the research, and evidence for practice. The scoping review was chosen due to its utility in synthesizing research evidence and providing comprehensive overviews of broad topics where many different study designs might be applicable. The literature was primarily searched in PubMed and Scopus, using the search string "upper quarter y balance test". In addition, a non-systematic search of Google Scholar was performed the reference lists were checked when screening the articles found by database search.

Studies were included if they met the following conditions: a) written in English b) including UQYBT as a primary or secondary variable. There were no restrictions on the date of the study, the population and the purpose of the study. For the purpose of collecting the reference values, the descriptive statistics and characteristics of the subjects (age, sex, sport, level of participation in sport) from the individual articles were extracted. The focus was on results normalised to limb length, as this approach enables comparison across individuals and groups. Consequently, the results are primarily expressed as a percentage of upper limb length (% ULL). In instances where values were not normalised, the raw values were considered. These instances are indicated in the supplementary table.

The literature was also synthesized narratively, addressing aspects of reliability, sex and sport differences, inter-limb asymmetries, limb dominance, injury risk, and the relationship of UQYBT results with other tests. This narrative synthesis allows for the integration of findings from diverse methodological approaches and facilitates a holistic understanding of the UQYBT's utility in both clinical and research settings.

Reference values

In total, 68 articles were identified (56 from the PubMed database, 11 from the Scopus database and one after an additional unsystematic search of the Google Scholar database). Due to unavailability of articles or insufficient reporting, reference values could not be obtained for 15 articles. Thus, 53 articles were used to extract normative values, which were separated by different types of sports. The reference values are collected in Supplementary File 1 (http://www.sportmont.ucg.ac.me/clanci/Ribnarik_Supplementary.pdf), divided into several sections based on sport types. In the following, subsections, the results are briefly summarized. Aspects such as sex and sport differences are addressed in later sections.

Strength and power sports

Five studies were included in the review, in which the subjects were representatives of "strength and power sports". In two studies, the subjects were from a specific sports discipline (one study Olympic weightlifting, one study CrossFit), and three studies stated the inclusion criteria as the subjects performing resistance training or weight training. Adults were the subjects in all of the studies reviewed. It should be noted that in the study by Guirelli et al. (2021), the authors used a modified version of the Y-test, while in the study by Silva et al. (2022), it is not entirely clear whether a modified version was used or not. The composite scores were relatively similar among the studies, mostly confined to 80 to 85% ULL. The results are shown in detail in Table 1 within the Supplementary file 1.

Swimming

Three studies included the swimmers (Table 2). One of the studies included only adult subjects, one study assessed only adolescent subjects and included both adolescent and adult subjects. Interestingly, mean composite scores range from 83.4 to 88.3% ULL in adults, and from 94.8 to 96.0% ULL in adolescents. The results are shown in detail in Table 2 within the Supplementary file 1.

Sports with rackets, bats and sticks

In the next larger group, due to the similarity of the functional requirements for the upper extremity, all the sports with rackets, sticks, bats and other similar equipment are included. In total, 11 studies were included, with baseball represented in seven studies, cricket and softball in two studies, and golf, hockey, lacrosse and tennis each in one study. The mean composite scores varied substantially; the lowest mean score was observed for female tennis players in 26-33 age group (77.9% ULL) and the highest in male baseball players (106.0% LL). The results are shown in detail in Table 3 within the Supplementary file 1.

Team sports with a ball

Team sports with a ball were represented in 15 studies. Handball and volleyball prevailed (in eight and seven studies, respectively), basketball players were included in two studies, while Australian and American football players were represented in one study each. The most detailed study by Bauer et al., (2021) included male and female handball players from different playing positions (goalkeepers, backcourts, pivots and wingers) were included. Mean composite scores again varied widely across sports and studies; values as low as 61.9% ULL were found in female volleyball players and 67.6% ULL in female handball players (Saccol et al., 2022), while the values exceed 100% ULL in some handball subgroups. It should be noted that two studies (Arora et al., 2021; Bennett et al., 2022) conducted a modified version of the test. The results are shown in detail in Table 4 within the Supplementary file 1.

Athletics and gymnastics

In this section, one study involved cross-country runners (range of mean composite scores: 79.8–83.5% ULL), one included track and field athletes from various disciplines (95.2–100.9% ULL), and one was conducted on children gymnasts (83.8–84.4% ULL). The results are shown in detail in Table 5 within the Supplementary file 1.

Martial arts

There were two studies included in this overview, both included the wrestlers. One of the studies provided separation

of wrestlers into two groups, indicating larger mean composite scores in Greco-Roman group (87.9% ULL) than freestyle group (83.4% ULL) (Tabasi et al., 2022). The results are shown in detail in Table 6 within the Supplementary file 1.

Military personnel

Four studies included military personnel or army recruits. All reported only a composite test result. It should be noted that in the study by Gottlieb et al. (2018), the result was normalised to the subjects' body height, not to the arm length, as is usually the case. Due to the different formula, the reported composite result deviated significantly from others, while the calculated standard deviation is not that different. Other than that, the studies were fairly consistent, reporting the composite score between 82.9% ULL and 89.5% ULL. The results are shown in detail in Table 7 within the Supplementary file 1.

Other sports

The next section summarises research that has covered broader groups of athletes or recreational athletes. It should be noted that two studies (Kim et al., 2020; Schwartzkopf-Phifer et al., 2021) did not normalise the result to the arm length. The composite scores were mostly in 80 – 90% ULL. Somewhat low mean composite scores were reported by Yildiz et al. (2022) for high impact sports (71.4% ULL), overhead sports (74.7% ULL) and overhead sports with sudden stops (72.4% ULL). The results are shown in detail in Table 8 within the Supplementary file 1.

Non-athlete population

Last group includes six additional studies in which the subjects were not athletes. Three of those studies included children as subjects and three adults. One study compared adolescent students with borderline intellectual functioning to age- and sex-matched controls (Bauer, Kammermeier, et al., 2021). Savitzky et al. (2021) provided only non-normalised results. In general, the mean values overlapped with values obtained with studies conducted on athletes, but were generally lower (e.g., no study reported a mean composite score >100% ULL). The results are shown in detail in Table 9 within the Supplementary file 1.

Reliability

Among the included studies, 6 aimed to provide reliability scores for UQYBT, and 5 reported reliabilities as a secondary result. In the following text, the results are summarized for each aspect of reliability. Relative reliability was assessed with intra-class correlation coefficient (ICC) in all studies. Some studies also provided measures of absolute reliability, such as standard error of measurement (SEM) and minimal detectable change (MDC). One study did not specify the type of reliability reported as a secondary outcome (Gottlieb et al., 2018), with ICC ranging from 0.80 to 0.89. In addition, it has been confirmed that there is a negligible effect of time of day on UQYBT scores (Heinbaugh et al., 2015).

Intra-examiner reliability

Intra-examiner reliability (measurements performed on the same day) was scarcely assessed. Xu et al. (2023) reported fair to good relative reliability for individual directions (ICC=0.70–0.86) and excellent reliability for the composite score (ICC=0.92) in adolescent swimmers. SEM ranged 0.48 to 0.82%, and MDC ranged from 1.11 to 2.23%. Williamson et al. (2019) reported nearly perfect reliability for limb length measurements (ICC=0.98 – 0.99).

Inter-examiner reliability

More studies are available on inter-examiner reliability. When scored by two examiners simultaneously (i.e., same trial is evaluated by the two examiners), the reliability seems to be perfect (ICC=0.99 – 1.0) (Gorman et al., 2012; Xu et al., 2023). When examiners record the test separately, the reliability is also excellent (ICC=0.98; SEM=0.35% ULL), which is also true for the modified version of the test (ICC=0.99; SEM=0.21% ULL) (Cramer et al., 2017). Studies reporting reliability as a secondary variable also report excellent or perfect inter-rater reliability (Ruffe et al., 2019; Mendez-Rebolledo, Ager, et al., 2022).

Test-retest reliability

Only two studies investigated test-retest (i.e., inter-visit) reliability. Westrick et al. (2012) reported excellent reliability of the composite score (ICC=0.91–0.92). Similarly, Gorman et al. (2012) reported excellent reliability of the medial (ICC=0.92), superolateral (ICC=0.94) and inferolateral (ICC=0.95) scores. SEM ranged from 2.2 to 2.9% ULL, and MDC ranged from 6.1 to 8.1% ULL. A study by Silva Barros et al. (2022) reported that test-retest reliability in theirs study range from fair to excellent (IC =0.55–0.97), but they included outcomes other than UQYBT.

In summary, relative reliability was consistently high, indicating excellent to perfect reliability in most cases. For intra-examiner reliability, limited studies showed fair to excellent reliability with ICC values ranging from 0.70 to 0.99. Inter-examiner reliability was extensively studied, with most studies reporting perfect or excellent reliability with ICC values approaching 1.0. Test-retest reliability was also reported to be excellent in the two studies that investigated it, with ICC values ranging from 0.91 to 0.95. Absolute reliability measures such as SEM and MDC were also reported in some studies, providing additional insight into the reliability of UQYBT measurements. Despite some variations, the overall evidence strongly supports the reliability of the UQYBT in different contexts and settings.

Sex differences

Sex differences represent one of the most intriguing aspects of the review. The 14 included articles allowed for a comparison of the results between women and men. Gorman et al. (2012) were the first to measure UQYBT, investigating differences between 51 men and 45 women. No statistically significant differences were reported, although men seemed to perform slightly better than women. The reported overall result for men was 85.1%, while the overall result for women was 83.9%. Guirelli et al. (2021) also reported slightly better results in men, except in the inferolateral direction for the latter. The absence of statistically significant differences between men and women is also highlighted in the article by Westrick et al. (2012), who tested a military student population. Although no statistically significant differences were found between the results of the male and female population, the overall results of females (82.9% for the dominant side and 85.2% for the non-dominant side) were slightly lower than males (86.5% for the dominant side and 88.1% for the non-dominant side) in this study.

Both Butler et al. (2014) and Bullock et al. (2017) included adult swimmers in their study. The latter study reports better results for male swimmers compared to female swimmers in all directions, with no statistically significant differences found only in the superolateral direction. Bullock et al. (2017) do not report overall results, but it can be seen from the results for each direction that in all directions, men reached further. Men generally performing better is confirmed by Teyhen et al. (2014) describing men's performance on average as 4.6% better than women's. Of the 14 mentioned studies, this one tested the largest sample (of the military population). The other studies reviewed do not provide actual values describing how much better men score on the test compared to women.

Taylor et al. (2016) who conducted a study among athletes from different disciplines, report that they identified differences between the overall performance of men and women, and between the medial and inferolateral performance of women and men. They also mention that the overall results obtained were significantly better than those reported by (Gorman et al., 2012). Furthermore, Schwiertz et al. (2019) presented results for both sexes combined and reported a statistically significant difference in the inferolateral direction, also in favour of men or better said boys, as the subjects included in this study were aged between 12 and 17 years, despite most authors reporting no statistically significant differences between men and women. The remaining studies where the results of men and women can be directly compared also report better results for men. The only exceptions are girls aged 10-11 (90.7%), who scored better overall on the right side than boys of the same age (88.4%), and girls aged 12-13, who scored better overall than boys aged 12-13 on both the left and the right side (Schwiertz et al., 2021).

As mentioned in the introduction, the UQYBT is most associated with the closed kinetic chain upper extremity stability test. The interest was to see whether there are differences between men and women for the latter as well. Taylor et al. (2016) reported statistically significant differences, with men scoring an average of 25 touches and women 22.9 touches. It should be noted that a modified version of the test was performed where to ensure better stability. The position of the upper limb was individually normalized, while the distance between the two targets remained constant. The authors also mention pre-established normative values that suggest that men perform better than women. Among other three reviewed articles (Westrick et al., 2012; Borms & Cools, 2018; Guirelli et al., 2021;) all reported better average scores for men.

Within- and between-sports differences

Most studies included in this review suggest that trained individuals generally outperform untrained ones, with continued improvement expected as the level of competition and player age increases (Taylor et al., 2016; Kokinda et al., 2018; Krysak et al., 2019; Schwiertz et al., 2020; Singla & Hussain, 2021). To illustrate, Taylor et al. (2016) noted that baseball players significantly outperformed athletes from other disciplines included in the study, such as basketball, volleyball, American football, lacrosse, track and field, and cross-country. Baseball players, whose sport demands substantial unilateral upper limb strength and stability, notably exceeded the performance of track and field, cross-country athletes, and lacrosse players on the UQYBT. Among the five studies testing baseball players, two had adolescents as subjects. The overall results for these younger participants did not surpass 90% in any study, a contrast to adult results which reported values above 90%, with Taylor et al. (2016) even noting values greater than 100%. When comparing cricket and baseball, all baseball results (across all ages) were superior to those for cricket. The overall outcomes for golf, hockey, and lacrosse are relatively similar, though older hockey players (seniors and U20) generally showed better performance in the medial direction than golfers and lacrosse players.

Studying athletes of different age groups, Borms and Cools (2018) reported the best overall results for men in the intermediate group, aged 26-33 years, and for women in the youngest group, 18-25 years. They also documented varying results by age group for other sports. The study indicated a lower performance of female volleyball players compared to female handball players, exclusively in the medial direction. Younger female handball players excelled over their volleyball counterparts (Saccol et al., 2022), a difference attributed to the distinct sport-specific movements characterizing each sport.

Two studies (Bauer et al., 2020; Bauer, Panzer, et al., 2021) both found better results for U14 handball players compared to U15, and similarly, 14-year-olds outperformed 15-year-olds. In another study by Bauer, Schwiertz, et al. (2021), the scores of handball players for different playing positions were described, showing no significant deviations for each playing position. Tabasi et al. (2022) discovered statistically significant differences among freestyle and Greco-Roman wrestlers, with the latter excelling on the UQYBT (87.98% vs. 83.38%). This superiority is attributed to the diverse training programs and extensive upper body training of Greco-Roman wrestlers. In addition, wrestlers exhibit significantly better scores than baseball pitchers (Myers et al., 2017), possibly highlighting the effect of predominantly close kinetic chain activities performed in wrestling (in contrast to predominantly open kinetic chain activities in baseball, ie., throwing) (Tooth et al., 2022).

Asymmetries and arm dominance

The UQYBT test is used to identify upper limb asymmetries, especially in sports that rely on one-arm dominance. Beyranvand et al. (2017) concluded that there is no difference between dominant and non-dominant arms in gymnasts with and without rounded shoulders. This is affirmed by two studies that found no statistically significant differences between dominant and non-dominant arms in UQYBT in injured and healthy baseball and softball players (Butler, Myers, et al., 2014; Chasse et al., 2018). Biaggi et al. (2021) also showed no statistical difference between the throwing and non-throwing arm in any direction of UQYBT in college softball players, a finding also found in baseball pitchers and other throwing athletes (Taylor et al., 2016; Borms et al., 2016; Bullock et al., 2018). No significant asymmetry reach was found in male and female swimmers in any direction (Butler, Arms, et al., 2014). In addition, composite scores are not different in sports where one side of the body does not dominate, like in CrossFit practitioners (Silva et al., 2022).

These results are confirmed by a study by two studies (Taylor et al., 2016; Westrick et al., 2012) in which healthy college students had no statistically significant differences in any direction between dominant and non-dominant sides. The limb asymmetry index was above 95% for superolateral side and above 98% for the M, IL, and composite score (Westrick et al., 2012). Based on the above results from these studies, it

appears that the UQYBT test scores do not exhibit asymmetries between the dominant and non-dominant arm in healthy athletes involved in throwing and other sports. The failure to detect asymmetries where one would expect to see detectable differences, such as injury or strong one-arm dominance, may be attributed to too few subjects, inaccurate test performance, or the test design itself not being specific and sensitive enough to detect asymmetries. However, as presented in the subsequent section, UQYBT may nonetheless be useful to assess injury risk.

Relationship to sports injuries

In cases where asymmetry between arms is detected, it may signify a higher risk of injury. For female cross-country runners, an Inferolateral (IL) reach difference of less than four centimetres correlated with a 75% lower probability of a running-related injury. Similarly, male cross-country runners with a four-centimetre Superior Lateral (SL) reach difference saw a seven-fold increase in the risk of injury in the hip, thigh, or knee region (Ruffe et al., 2019). Elite football players with high posteromedial asymmetry, good agility performance, and no previous injury history had a 2.69 times increased risk of injury, and those with a past injury had a 3.26 times higher risk (Bennett et al., 2022). Analyses also displayed asymmetries among 14-, 15-, 16-, and 18-year-old male and female handball players, with greater asymmetry correlating with a higher probability of musculoskeletal injuries (Bauer, Panzer, et al., 2021). Contrarily, scores below 81.1% on the composite UQYBT have been linked to 2.66 times increase in injury likelihood, and scores in the Superior Lateral (SL) direction have shown 2.08 times increase in injury risk among healthy Armed Forces personnel (Campbell et al., 2022). A most recent study on handball players indicated that only the presence of an inferolateral reach asymmetry higher than 7.75% ULL was associated with a 2.18-times higher lower limb injury risk, but not upper or whole-body injury risk, suggesting that UQYBT has limited value to assess the risk of sport-related injuries in handball (Bauer et al., 2023). The test was not found to be a significant predictor of injury in female soldiers (Gottlieb et al., 2018) and another cohort of handballers (Mussigmann et al., 2020). However, experiencing pain during the test was associated with 3.3-fold higher attrition rates in infantry recruits during the first year of training (Fleischmann et al., 2023).

Injury history has been observed to impact the Superior Lateral (SL) reach in overhead athletes. Those with a shoulder injury recorded a significantly lower mean reach distance compared to their healthy counterparts (Kim et al., 2020). However, this is in contrast to (Chasse et al., 2018) who concluded that injury history does not influence the UQYBT results. Gymnasts with rounded shoulders have displayed poorer UQYBT results compared to those with normal anatomical shoulder shapes (Bennett et al., 2022). Moreover, male professional volleyball players with infraspinatus atrophy showed significantly lower superior-lateral and inferior-lateral reach UQYBT results compared to healthy individuals and their non-throwing side (Contemori et al., 2018). However, no change was noted for the UQYBT test values during the season in volleyball players, making usefulness of this test in volleyball players questionable (Tooth et al., 2023). Shoulder impingement syndrome has impacted the Medial (M) and Inferolateral (IL) reach direction in adults (Hazar et al., 2014), while scapular dyskinesis has not shown a significant effect on the UQYBT (Pires & Camargo, 2018). Additionally, CrossFit practitioners with shoulder pain did not show a statistically different composite UQYBT compared to the side without pain (Silva et al., 2022).

These insights highlight the need to consider specific injuries and their impact on different reach directions of the UQYBT, aiding in the development of targeted prevention and rehabilitation programs.

Correlations and determinants

Anthropometry

Anthropometric measurements like height and weight can indirectly impact the test results by influencing the percentage of muscle mass and the length of the upper limb. A study on female soldiers revealed a slight positive correlation between average UQYBT scores and both height (right side: r=0.1; left side: r=0.11) and weight (right side r=−0.25; left side: r=−0.26) (Gottlieb et al., 2018). This suggests that anthropometric factors do hold some sway over UQYBT scores, albeit weakly.

Strength

Research indicates various correlations between the components of the UQYBT test and the strength of different muscle groups. Among CrossFit practitioners without musculoskeletal shoulder pain, a positive association exists between the superolateral component and the strength of the shoulder's abductor muscles. This correlation is absent in practitioners with shoulder pain, who instead show a positive association between the strength of external shoulder rotators and the medial component of the UQYBT test (Silva et al., 2022). In the dominant limb, moderate positive correlations are observed: between superolateral reach and serratus anterior muscle isometric strength (r=0.45), medial reach and lower trapezius muscle isometric strength (r=0.44), and inferolateral reach with both serratus anterior muscle (r=0.53) and lower trapezius muscle (r=0.53) isometric strength. Additional associations include rotators of the trunk (r=0.49), and lateral trunk flexor strength (r=0.56), as well as between the composite score and the strength of the serratus anterior muscle (r=0.52), lower trapezius muscle (r=0.58), rotators of the trunk (r=0.45), and lateral trunk rotators (r=0.51) in recreational swimmers. A negative moderate correlation is present between inferolateral reach and trunk flexion endurance time (r=−0.47) in the same group (Silva Barros et al., 2022). In addition, UQYBT test results were in moderate positive correlation with McGill trunk endurance test (r=0.46) when assessed on a sample of male collegiate athletes (Nuhmani, 2022). However, in another study, there was no difference in UQYBT results between basketball players with good and poor core stabilization (based on Sahrmann Core Stability Test; Chan et al., 2020), and there was also no effect of instructing the participants to activate their core musculature during the test (Arora et al., 2021).

Furthermore, lower trapezius isometric strength demonstrates a positive relationship with the inferolateral UQYBT reach, accounting for 70% of the UQYBT variability in the inferolateral direction (Mendez-Rebolledo, Cools, et al., 2022). However, no correlation is found between the variables of the UQYBT test and the strength of back muscles in cricket players (Singla et al., 2018). In conclusion, various studies

highlight the diverse relationships between the UQYBT test components and muscle group strength. These findings emphasize the variable associations between UQYBT test components and muscle strength, suggesting the influence of specific sports and physical conditions on these relationships.

Clinical tests

In amateur volleyball players, a negative moderate correlation was found with inferolateral UQYBT (r=−0.57) and the UQYBT composite score (r=−0.43) and the Active joint position sense measurements at 90° of internal rotation (Mendez-Rebolledo, Ager, et al., 2022). This article also disclosed that the active joint position sense measurements at 90° of internal rotation have the greatest influence on the change in the inferolateral direction of the UQYBT test. However, there was no association between the medial reach in UQYBT and Closed Kinetic Chain Upper-Extremity Stability Test performances. On the other hand, Taylor et al. (2016) established that there is a very low correlation between the Closed Kinetic Chain Upper-Extremity Stability Test scores and UQYBT composite score (r=0.04–0.18) in healthy college athletes. A statistically significant positive association was also found between medial reach of UQYBT test and the Closed Kinetic Chain Upper-Extremity Stability Test in healthy CrossFit practitioners (Silva et al., 2022). The reason for the low correlation may be that the two tests assess different abilities. The Closed Kinetic Chain Upper-Extremity Stability Test includes power, speed, and stability, whereas the UQYBT challenges the limits of stability of an athlete, including components of balance, proprioception, and mobility of the thoracic spine and scapula. Finally, In male adolescent handball players, various correlations with the Bourban test were noted for both throwing and non-throwing hands across different directions and composite scores (Bauer et al., 2022).

Sports performance

In addition to correlations with the strength of individual muscle groups, the UQYBT test was also found to correlate with other movement components important for sports performance. Bartolomeu et al. (2023) found a positive moderate correlation between swimming speed and UQYBT test scores of left (r=0.54) and right hand (r=0.57). In youth handball players there was a small correlation between UQYBT performance and throwing velocity (TV) or accuracy (A) of the throw (13-year-old females: TV: $-0.01 \leq r \leq -0.37$; A: $0.01 \leq r \leq 0.31$; 14-year-old males: TV:$0.10 \leq r \leq 0.45$; A: $-0.01 \leq r \leq -0.51$; 15-year-old males: TV: $0.06 \leq r \leq 0.34$; A: $0.01 \leq r \leq -0.45$) (Bauer, Schedler, et al., 2020). More studies are urgently needed to assess relationships between UQYBT and sport-specific performance.

Effects of interventions

Following upper-extremity balance training with Biodex device, the UQYBT composite score increased for ~9-10 %, which was more than in the control group that performed upper extremity resistance training (Abdelraouf et al., 2022). Moreover, core stability training was reported to increase UQYBT composite scores by as much as 15% (Jha et al., 2022). Furthermore, Bodyblade™ training in athletes with traumatic anterior shoulder instability improved the scores for ~4-6 % (Pulido et al., 2023). Exercises focused on improving awareness of lumbar spine position and thoracic spine mobility did not improve the UQYBT in any direction in active females, however, the sample size was very small (n=12) (Schwartzkopf-Phifer et al., 2021). Savitzky et al. (2021) compared two approaches for rotator cuff rehabilitation: 1) ShoulderSphere, an innovative device that uses resistance to centrifugal force, 2) TheraBand as a traditional device that uses resistance to elasticity. Both approaches improved inferolateral direction with large effects size (d=0.75 to 0.89), but there were no group × time interactions. Next, performing the FIFA 11+ Shoulder programme for 8 weeks resulted in an increase (+8% ULL) in composite score (Zarei et al., 2021). After a local vibration application shoulder joints, an increase in UQYBT scores was reported, with mean non-normalized composite score increasing from 211.1±26.8 cm to 244.3±30.1 cm (Jung & Moon, 2015). In contrast, application of Kinesiotape did not improve immediate UQYBT scores in a male collegiate athletic population with rounded shoulder posture (Dittmer et al., 2021).

Three studies have also assessed the influence of fatigue on UQYBT. Bauer, Hagen, et al. (2020) effects of fatigue protocol (consisting of sets of push-ups until failure) on throwing performance and UQYBT scores in male adolescent handball players. Fatigue caused a significant decrease in throwing velocity (−3%) and superolateral reach direction (throwing arm: −5%; non-throwing arm reach: −10%) and the composite score (throwing arm: −2%; non-throwing arm: −4%), but not for the medial and the inferolateral reach directions. Finally, Salo & Chaconas (2017) demonstrated ~2–12 cm reductions in absolute scores after upper extremity fatigue protocol in recreational weightlifters.

In summary, the various impacts on UQYBT composite scores highlight the sensitivity of the UQYBT to different interventions, underlining its practical utility as a measure in upper extremity balance training and rehabilitation. The marked improvement in UQYBT scores with the use of specialized devices and training methods, such as the Biodex device and core stability training, underscores their effectiveness. This underlines the significance of the UQYBT as a discerning tool for evaluating and guiding upper extremity balance and stability interventions, ensuring the application of the most beneficial and efficient methods for individuals.

Conclusions

The scoping review UQYBT reveals its utility in evaluating upper limb stability, predicting injury risks, and informing training regimens across various sports disciplines. The aggregation of limb-length-normalized data is a step towards enhancing the test's standardization. Our analysis confirms the UQYBT's reliability and consistency across diverse populations, reinforcing its validity as a functional assessment tool. The relationship between UQYBT scores and muscle is complex, with sport-specific variations suggesting a need for a careful interpretation. In some sports, the UQYBT may serve as a predictor for potential injuries. Ultimately, the UQYBT stands out as a valuable component of an athlete's assessment protocol, with its ability to reflect underlying musculoskeletal functions and potential for individualization of training in line with sport-specific demands. It is crucial for future research to further explore this relationship, enabling an evidence-based application of the UQYBT that could help improve injury prevention strategies and elevate athletic performance through training interventions.

Acknowledgments
There are no acknowledgments.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding: The study was supported by the Slovenian Research Agency through the research program KINSPO - Kinesiology for the effectiveness and prevention of musculoskeletal injuries in sports (P5-0443).

Received: 10 November 2023 | **Accepted:** 17 January 2024 | **Published:** 01 February 2024

References

Abdelraouf, O. R., Abdel-Aziem, A. A., Ghally, S. A., Osama, L. A., Dawood, R. S., Yehia, A. M., … & Radwan, R. E. (2022). Innovative Use of Biodex Balance System to Improve Dynamic Stabilization and Function of Upper Quarter in Recreational Weightlifters: A Randomized Controlled Trial. *Medicina (Kaunas, Lithuania)*, *58*(11). https://doi.org/10.3390/medicina58111631

Arora, C., Singh, P., & Varghese, V. (2021). Biomechanics of core musculature on upper extremity performance in basketball players. *Journal of Bodywork and Movement Therapies*, *27*, 127–133. https://doi.org/10.1016/j.jbmt.2021.02.023

Bartolomeu, R. F., Sampaio, T., Oliveira, J. P., Barbosa, T. M., & Morais, J. E. (2023). Association between the Upper Quarter Dynamic Balance, Anthropometrics, Kinematics, and Swimming Speed. *Journal of Functional Morphology and Kinesiology*, *8*(3), 96. https://doi.org/10.3390/jfmk8030096

Bauer, J., Gruber, M., & Muehlbauer, T. (2022). Correlations between core muscle strength endurance and upper-extremity performance in adolescent male sub-elite handball players. *Frontiers in Sports and Active Living*, *4*. https://doi.org/10.3389/fspor.2022.1050279

Bauer, J., Hagen, M., Weisz, N., & Muehlbauer, T. (2020). The Influence of Fatigue on Throwing and YBT-UQ Performance in Male Adolescent Handball Players. *Frontiers in Sports and Active Living*, *2*. https://doi.org/10.3389/fspor.2020.00081

Bauer, J., Kammermeier, H., Schwiertz, G., & Muehlbauer, T. (2021). Comparison of lower and upper quarter y balance test performance in adolescent students with borderline intellectual functioning compared to age-and sex-matched controls. *Children*, *8*(9). https://doi.org/10.3390/CHILDREN8090805

Bauer, J., Panzer, S., Gruber, M., & Muehlbauer, T. (2023). Associations between upper quarter Y-balance test performance and sport-related injuries in adolescent handball players. *Frontiers in Sports and Active Living*, *5*. https://doi.org/10.3389/fspor.2023.1076373

Bauer, J., Panzer, S., & Muehlbauer, T. (2021). Side differences of upper quarter Y balance test performance in sub-elite young male and female handball players with different ages. *BMC Sports Science, Medicine and Rehabilitation*, *13*(1), 141. https://doi.org/10.1186/s13102-021-00364-3

Bauer, J., Schedler, S., Fischer, S., & Muehlbauer, T. (2020). Relationship between Upper Quarter y Balance Test performance and throwing proficiency in adolescent Olympic handball players. *BMC Sports Science, Medicine and Rehabilitation*, *12*(1). https://doi.org/10.1186/s13102-020-00199-4

Bauer, J., Schwiertz, G., & Muehlbauer, T. (2021). Diverging Playing Positions do not Lead to Differences in YBT-UQ Performance in Youth Handball Players. *Sports Medicine International Open*, *05*(03), E99–E103. https://doi.org/10.1055/a-1647-7174

Bennett, H., Chalmers, S., Milanese, S., & Fuller, J. (2022). The association between Y-balance test scores, injury, and physical performance in elite adolescent Australian footballers. *Journal of Science and Medicine in Sport*, *25*(4), 306–311. https://doi.org/10.1016/j.jsams.2021.10.014

Beyranvand, R., Mirnasouri, R., Mollahoseini, S., & Mostofi, S. (2017). The functional stability of the upper limbs in healthy and rounded shoulder gymnasts. *Science of Gymnastics Journal*, *9*(3), 279–290.

Bhat, R., & Moiz, J. A. (2013). Comparison of dynamic balance in collegiate field hockey and football players using star excursion balance test. *Asian Journal of Sports Medicine*, *4*(3), 221–229. https://doi.org/10.5812/asjsm.34287

Biaggi, K., Farmer, B., Hobson, M., Self, C., & Grindstaff, T. L. (2021). Shoulder Strength and Range of Motion in Healthy Collegiate Softball Players. *Journal of Athletic Training*, *56*(10), 1086–1093. https://doi.org/10.4085/301-20

Borms, D., & Cools, A. (2018). Upper-Extremity Functional Performance Tests: Reference Values for Overhead Athletes. *International Journal of Sports Medicine*, *39*(6), 433–441. https://doi.org/10.1055/a-0573-1388

Borms, D., Maenhout, A., & Cools, A. M. (2016). Upper quadrant field tests and isokinetic upper limb strength in overhead athletes. *Journal of Athletic Training*, *51*(10), 789–796. https://doi.org/10.4085/1062-6050-51.12.06

Bullock, G. S., Brookreson, N., Knab, A. M., & Butler, R. J. (2017). Examining fundamental movement competency and closed-chain upper-extremity dynamic balance in swimmers. *Journal of Strength and Conditioning Research*, *31*(6), 1544–1551. https://doi.org/10.1519/JSC.0000000000001627

Bullock, G. S., Schmitt, A. C., Chasse, P. M., Little, B. A., Diehl, L. H., & Butler, R. J. (2018). The relationship between trunk rotation, upper quarter dynamic stability, and pitch velocity. *Journal of Strength and Conditioning Research*, *32*(1), 261–266. https://doi.org/10.1519/JSC.0000000000001772

Butler, R., Arms, J., Reiman, M., Plisky, P., Kiesel, K., Taylor, D., & Queen, R. (2014). Sex differences in dynamic closed kinetic chain upper quarter function in collegiate swimmers. *Journal of Athletic Training*, *49*(4), 442–446. https://doi.org/10.4085/1062-6050-49.3.17

Butler, R., Myers, H., Black, D., Kiesel, K., Plisky, P., Moorman, C., & Queen, R. (2014). Bilateral differences in the upper quarter function of high school aged baseball and softball players. *International Journal of Sports Physical Therapy*, *9*(4), 518–524. http://www.ncbi.nlm.nih.gov/pubmed/25133080%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4127514

Campbell, K. E., Parent, E. C., Crumback, D. J., & Hebert, J. S. (2022). Predicting Upper Quadrant Musculoskeletal Injuries in the Military: A Cohort Study. *Medicine and Science in Sports and Exercise*, *54*(2), 337–344. https://doi.org/10.1249/MSS.0000000000002789

Chan, E. W. M., Hamid, M. S. A., Nadzalan, A. M., & Hafiz, E. (2020). Abdominal muscle activation: An EMG study of the Sahrmann five-level core stability test. *Hong Kong Physiotherapy Journal*, *40*(2), 89–97. https://doi.org/10.1142/S1013702520500080

Chasse, P., Bullock, G. S., Schmitt, A. C., Little, B. A., Diehl, L. H., & Butler, R. J. (2018). the Relationship Between Trunk Rotation, Upper Quarter Dynamic Stability, and the Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Shoulder and Elbow Score in Division I Collegiate Pitchers. *International Journal of Sports Physical Therapy*, *13*(5), 819–827. https://doi.org/10.26603/ijspt20180819

Clarke, F., Koutedakis, Y., Wilson, M., & Wyon, M. (2019). Associations between balance ability and dance performance using field balance tests. *Medical Problems of Performing Artists*, *34*(3), 154–160. https://doi.org/10.21091/mppa.2019.3026

Contemori, S., Biscarini, A., Botti, F. M., Busti, D., Panichi, R., & Pettorossi, V. E. (2018). Sensorimotor control of the shoulder in professional volleyball players with isolated infraspinatus muscle atrophy. *Journal of Sport Rehabilitation*, *27*(4), 371–379. https://doi.org/10.1123/jsr.2016-0183

Coughlan, G., Fullam, K., Delahunt, E., Gissane, C., & Caulfield, B. (2012). A Comparison Between Performance on Selected Directions of the Star Excursion Balance Test and the Y Balance Test. *Journal of Athletic Training*, *47*(4), 366–371. http://myaccess.library.utoronto.ca/login?url=https://search.proquest.com/docview/ 1130649597?accountid=14771%0Ahttp://bf4dv7zn3u.search.ser ialssolutions.com/dire ctLink?&atitle=A+Co mparison+Between +Performance+on+Selected +Directions+of+the+Star+Excursion+B

Cramer, J., Quintero, M., Rhinehart, A., Rutherford, C., Nasypany, A., May, J., & Baker, R. T. (2017). Exploration of score agreement on a modified upper quarter y-balance test kit as compared to the upper quarter y-balance test. *International Journal of Sports Physical Therapy*, *12*(1), 117–124. http://www.ncbi.nlm.nih.gov/pubmed/28217422

Dittmer, A., Tomchuk, D., & Fontenot, D. R. (2021). Immediate effects of limb rotational kinesio tape application on upper quarter Y-balance test scores. *Journal of Sport Rehabilitation*, *30*(4), 552–558. https://doi.org/10.1123/JSR.2019-0145

Falsone, S. A., Gross, M. T., Guskiewicz, K. M., & Schneider, R. A. (2002). One-Arm Hop Test: Reliability and Effects of Arm Dominance. *Journal of Orthopaedic & Sports Physical Therapy*, *32*(3), 98–103. https://doi.org/10.2519/jospt.2002.32.3.98

Fleischmann, C., Yanovich, R., Milgrom, C., Eliyahu, U., Gez, H., Heled, Y., & Finestone, A. S. (2023). Utility of preinduction tests as predictors of attrition in infantry recruits: A prospective study. *BMJ Military Health*, *169*(3), 225–230. https://doi.org/10.1136/bmjmilitary-2021-001776

Goldbeck, T. G., & Davies, G. J. (2000). Test-Retest Reliability of the Closed Kinetic Chain Upper Extremity Stability Test: A Clinical Field Test. *Journal of Sport Rehabilitation*, *9*(1), 35–45. https://doi.org/10.1123/jsr.9.1.35

Gorman, P. P., Butler, R. J., Plisky, P. J., & Kiesel, K. B. (2012). Upper quarter y balance test: Reliability and performance comparison between genders in active adults. *Journal of Strength and Conditioning Research*, *26*(11), 3043–3048. https://doi.org/10.1519/JSC.0b013e3182472fdb

Gottlieb, U., Kelman, D., & Springer, S. (2018). Evaluation of two simple

functional tests to predict attrition from combat service in female light infantry soldiers. *Medical Science Monitor*, *24*, 9334–9341. https://doi.org/10.12659/MSM.911672

Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. *Journal of Athletic Training*, *47*(3), 339–357. https://doi.org/10.4085/1062-6050-47.3.08

Guirelli, A. R., dos Santos, J. M., Cabral, E. M. G., Pinto, J. P. C., De Lima, G. A., & Felicio, L. R. (2021). Relationship between upper limb physical performance tests and muscle strength of scapular, shoulder and spine stabilizers: A cross-sectional study. *Journal of Bodywork and Movement Therapies*, *27*, 612–619. https://doi.org/10.1016/j.jbmt.2021.05.014

Hazar, Z., Ulug, N., & Yuksel, I. (2014). Upper quarter Y-balance test score of patients with shoulder impingement syndrome. *Orthopaedic Journal of Sports Medicine*, *2*(11). https://doi.org/10.1177/2325967114S00275

Hegedus, E. J., Vidt, M. E., & Tarara, D. T. (2014). The best combination of physical performance and self-report measures to capture function in three patient groups. *Physical Therapy Reviews*, *19*(3), 196–203. https://doi.org/10.1179/1743288X13Y.0000000121

Heinbaugh, E. M., Smith, D. T., Zhu, Q., Wilson, M. A., & Dai, B. (2015). The effect of time-of-day on static and dynamic balance in recreational athletes. *Sports Biomechanics*, *14*(3), 361–373. https://doi.org/10.1080/14763141.2015.1084036

Hrysomallis, C. (2007). Relationship between balance ability, training and sports injury risk. *Sports Medicine*, *37*(6), 547–556. https://doi.org/10.2165/00007256-200737060-00007

Hrysomallis, C. (2011). Balance ability and athletic performance. *Sports Medicine*, *41*(3), 221–232.

Jha, P., Nuhmani, S., Kapoor, G., Muslem, W. H. Al, Joseph, R., Kachanathu, S. J., & Alsaadi, S. M. (2022). Efficacy of core stability training on upper extremity performance in collegiate athletes. *Journal of Musculoskeletal Neuronal Interactions*, *22*(4), 498–503.

Jung, D. E., & Moon, D. C. (2015). Effect of the application of local vibration in scaption on joint stability. *Journal of Physical Therapy Science*, *27*(1), 115–116. https://doi.org/10.1589/jpts.27.115

Kiers, H., Van Dieën, J., Dekkers, H., Wittink, H., & Vanhees, L. (2013). A systematic review of the relationship between physical activities in sports or daily life and postural sway in upright stance. *Sports Medicine*, *43*(11), 1171–1189. https://doi.org/10.1007/s40279-013-0082-5

Kim, Y., Lee, J. M., Wellsandt, E., & Rosen, A. B. (2020). Comparison of shoulder range of motion, strength, and upper quarter dynamic balance between NCAA division I overhead athletes with and without a history of shoulder injury. *Physical Therapy in Sport*, *42*, 53–60. https://doi.org/10.1016/j.ptsp.2019.12.007

Kokinda, M., Jesensky, M., Kandrac, R., Kicura, D., Turek, M., & Chovanova, E. (2018). Examination of age-related core stability and dynamic balance in hockey players. *Sport Mont*, *16*(2), 21–26. https://doi.org/10.26773/smj.180604

Krysak, S., Harnish, C. R., Plisky, P. J., Knab, A. M., & Bullock, G. S. (2019). Fundamental Movement and Dynamic Balance Disparities Among Varying Skill Levels in Golfers. *International Journal of Sports Physical Therapy*, *14*(4), 537–545. https://doi.org/10.26603/ijspt20190537

Mendez-Rebolledo, G., Ager, A. L., Ledezma, D., Montanez, J., Guerrero-Henriquez, J., & Cruz-Montecinos, C. (2022). Role of active joint position sense on the upper extremity functional performance tests in college volleyball players. *PeerJ*, *10*. https://doi.org/10.7717/peerj.13564

Mendez-Rebolledo, G., Cools, A. M., Ramirez-Campillo, R., Quiroz-Aldea, E., & Habechian, F. A. P. (2022). Association Between Lower Trapezius Isometric Strength and Y-Balance Test Upper Quarter Performance in College Volleyball Players. *Journal of Sport Rehabilitation*, *31*(2), 140–145. https://doi.org/10.1123/jsr.2021-0048

Mussigmann, T., Lagniaux, F., Trouveroy, G., Drigny, J., Quesada, C., & Edouard, P. (2020). Association between sensorimotor function and shoulder injury: Prospective pilot study in a cohort of handballers. *Journal de Traumatologie Du Sport*, *37*(1), 10–19. https://doi.org/10.1016/j.jts.2019.12.007

Myers, H., Poletti, M., & Butler, R. J. (2017). Difference in functional performance on the Upper-Quarter Y-Balance Test between high school baseball players and wrestlers. *Journal of Sport Rehabilitation*, *26*(3), 253–259. https://doi.org/10.1123/jsr.2015-0168

Nuhmani, S. (2022). Correlation between Core Stability and Upper-Extremity Performance in Male Collegiate Athletes. *Medicina (Lithuania)*, *58*(8). https://doi.org/10.3390/medicina58080982

Pires, E. D., & Camargo, P. R. (2018). Analysis of the kinetic chain in asymptomatic individuals with and without scapular dyskinesis. *Clinical Biomechanics*, *54*, 8–15. https://doi.org/10.1016/j.clinbiomech.2018.02.017

Plisky, P. J., Gorman, P. P., Butler, R. J., Kiesel, K. B., Underwood, F. B., & Elkins, B. (2009). The reliability of an instrumented device for measuring components of the star excursion balance test. *North American Journal of Sports Physical Therapy : NAJSPT*, *4*(2), 92–99. http://www.ncbi.nlm.nih.gov/pubmed/21509114%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC2953327

Powden, C. J., Dodds, T. K., & Gabriel, E. H. (2019). the Reliability of the Star Excursion Balance Test and Lower Quarter Y-Balance Test in Healthy Adults: a Systematic Review. *International Journal of Sports Physical Therapy*, *14*(5), 683–694. https://doi.org/10.26603/ijspt20190683

Pulido, V., Alvar, B., & Behm, D. (2023). Bodyblade™ Training in Athletes with Traumatic Anterior Shoulder Instability. *International Journal of Sports Physical Therapy*, *18*(1), 188–198. https://doi.org/10.26603/001c.65900

Ruffe, N. J., Sorce, S. R., Rosenthal, M. D., & Rauh, M. J. (2019). Lower Quarter- and Upper Quarter Y Balance Tests As Predictors of Running-Related Injuries in High School Cross-Country Runners. *International Journal of Sports Physical Therapy*, *14*(5), 695–706. https://doi.org/10.26603/ijspt20190695

Sabchuk, R. A. C., Bento, P. C. B., & Rodacki, A. L. F. (2012). Comparison between field balance tests and force platform. *Revista Brasileira de Medicina Do Esporte*, *18*(6), 404–408. https://doi.org/10.1590/S1517-86922012000600012

Saccol, M. F., Zanca, G. G., Machado, R. O., Teixeira, L. P., Löbell, R., Cools, A., & Mota, C. B. (2022). Shoulder Strength and Upper Body Field Performance Tests in Young Female Handball and Volleyball Athletes: Are There Differences Between Sports? *Journal of Sport Rehabilitation*, *31*(2), 191–198. https://doi.org/10.1123/jsr.2021-0221

Salo, T. D., & Chaconas, E. (2017). The Effect of Fatigue on Upper Quarter Y-Balance Test Scores in Recreational Weightlifters: A Randomized Controlled Trial. *International Journal of Sports Physical Therapy*, *12*(2), 199–205. http://www.ncbi.nlm.nih.gov/pubmed/28515974%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5380862

Savitzky, J. A., Abrams, L. R., Galluzzo, N. A., Ostrow, S. P., Protosow, T. J., Liu, S. A., … & Friel, K. (2021). Effects of a Novel Rotator Cuff Rehabilitation Device on Shoulder Strength and Function. *Journal of Strength and Conditioning Research*, *35*(12), 3355–3363. https://doi.org/10.1519/JSC.0000000000003347

Schwartzkopf-Phifer, K., Leach, S., Whetstone, K., Brown, K., & Matsel, K. (2021). The effect of a novel training program to improve trunk stability push up performance in active females: A pilot study. *International Journal of Sports Physical Therapy*, *16*(5), 1345–1354. https://doi.org/10.26603/001c.28055

Schwiertz, G., Bauer, J., & Muehlbauer, T. (2021). Upper Quarter Y Balance test performance: Normative values for healthy youth aged 10 to 17 years. *PLoS ONE*, *16*(6 June). https://doi.org/10.1371/journal.pone.0253144

Schwiertz, G., Beurskens, R., & Muehlbauer, T. (2020). Discriminative validity of the lower and upper quarter Y balance test performance: a comparison between healthy trained and untrained youth. *BMC Sports Science, Medicine and Rehabilitation*, *12*(1). https://doi.org/10.1186/s13102-020-00220-w

Schwiertz, G., Brueckner, D., Schedler, S., Kiss, R., & Muehlbauer, T. (2019). Reliability and Minimal Detectable Change of the Upper Quarter Y-Balance Test in Healthy Adolescents Aged 12 To 17 Years. *International Journal of Sports Physical Therapy*, *14*(6), 927–934. https://doi.org/10.26603/ijspt20190927

Silva Barros, B. R. da, Cavalcanti, I. B. S., Silva Júnior, N. da, & Sousa, C. de O. (2022). Correlation between upper limb function and clinical measures of shoulder and trunk mobility and strength in overhead athletes with shoulder pain. *Physical Therapy in Sport*, *55*, 12–20. https://doi.org/10.1016/j.ptsp.2022.02.001

Silva, E. R., Maffulli, N., Migliorini, F., Santos, G. M., de Menezes, F. S., & Okubo, R. (2022). Function, strength, and muscle activation of the shoulder complex in Crossfit practitioners with and without pain: a cross-sectional observational study. *Journal of Orthopaedic Surgery and Research*, *17*(1). https://doi.org/10.1186/s13018-022-02915-x

Singla, D., & Hussain, M. E. (2021). Variations in cricket players' upper body dynamic balance across different levels of competition. *International Journal of Adolescent Medicine and Health*, *33*(5). https://doi.org/10.1515/ijamh-2019-0015

Singla, D., Hussain, M. E., & Bhati, P. (2018). Correlation Between Upper Body Balance, Muscle Strength, and Power in Cricketers Belonging to Different Age Groups. *Journal of Chiropractic Medicine*, *17*(3), 160–166. https://doi.org/10.1016/j.jcm.2018.03.002

Tabasi, S. R., Norasteh, A. A., Mirzaei, B., & Zarei, H. (2022). Proprioception and dynamic balance performance in wrestlers: Freestyle vs. Greco-Romana. *Science and Sports*, *37*(5–6), 494.e1-494.e7. https://doi.org/10.1016/j.scispo.2021.06.011

Taylor, J. B., Wright, A. A., Smoliga, J. M., DePew, J. T., & Hegedus, E. J. (2016). Upper-extremity physical-performance tests in college athletes.

Journal of Sport Rehabilitation, *25*(2), 146–154. https://doi.org/10.1123/jsr.2014-0296

Teyhen, D. S., Riebel, M. A., McArthur, D. R., Savini, M., Jones, M. J., Goffar, S. L., … & Plisky, P. J. (2014). Normative Data and the Influence of Age and Gender on Power, Balance, Flexibility, and Functional Movement in Healthy Service Members. *Military Medicine*, *179*(4), 413–420.https://search.proquest.com/docview/1522546748?accountid=13828%0Ahttp://find.shef.ac.uk/openurl/44SFD/44SFD_services_page?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=article&sid=ProQ:ProQ%3Asciencejournals&atitle=Normative+Data+and+

Tooth, C., Schwartz, C., Ann, C., Croisier, J. L., Gofflot, A., Stephen, B., & Forthomme, B. (2022). Upper limb functional testing in athletes: A Delphi study. *Shoulder and Elbow*. https://doi.org/10.1177/17585732221101880

Tooth, C., Schwartz, C., Gofflot, A., Bornheim, S., Croisier, J. L., & Forthomme, B. (2023). Preseason shoulder screening in volleyball players: is there any change during season? *JSES International*, *7*(4), 662–667. https://doi.org/10.1016/j.jseint.2023.03.022

Trajković, N., Kozinc, Ž., Smajla, D., & Šarabon, N. (2021). Relationship between ankle strength and range of motion and postural stability during single-leg quiet stance in trained athletes. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-91337-6

Velarde-Sotres, Á., Bores-Cerezal, A., Mecías-Calvo, M., Carvajal-Altamiranda, S., & Calleja-González, J. (2021). Validity, reliability and reproducibility of octobalance test as tool to measure the upper limb compared to modified-upper quarter y-balance test. *International Journal of Environmental Research and Public Health*, *18*(10). https://doi.org/10.3390/ijerph18105057

Westrick, R. B., Miller, J. M., Carow, S. D., & Gerber, J. P. (2012). Exploration of the y-balance test for assessment of upper quarter closed kinetic chain performance. *International Journal of Sports Physical Therapy*, *7*(2), 139–147. http://www.ncbi.nlm.nih.gov/pubmed/22530188%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3325634

Williamson, J. D., Lawson, B. L., Sigley, D., Nasypany, A., & Baker, R. T. (2019). Intra- and nter-rater reliability for limb length measurement and trial error assessment of the upper quarter y-balance test in healthy adults. *International Journal of Sports Physical Therapy*, *14*(5), 707–714. http://www.ncbi.nlm.nih.gov/pubmed/31598408

Xu, H. R., Zhang, Y. H., Mao, Y., Ngo, T. L., Zhang, Q., He, G. … & Wang, X. Q. (2023). Validity and reliability of upper extremity star excursion balance test in adolescent swimmers. *Journal of Exercise Science and Fitness*, *21*(2), 210–217. https://doi.org/10.1016/j.jesf.2023.02.003

Yildiz, T. I., Turhan, E., Ocguder, D. A., Yaman, F., Huri, G., & Duzgun, I. (2022). Functional Performance Tests Reveal Promising Results at 6 Months After Shoulder Stabilization Surgery. *Sports Health*. https://doi.org/10.1177/19417381221141075

Zarei, M., Eshghi, S., & Hosseinzadeh, M. (2021). The effect of a shoulder injury prevention programme on proprioception and dynamic stability of young volleyball players; a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, *13*(1). https://doi.org/10.1186/s13102-021-00300-5

Zemková, E. (2022). Physiological Mechanisms of Exercise and Its Effects on Postural Sway: Does Sport Make a Difference? *Frontiers in Physiology*, *13*. https://doi.org/10.3389/fphys.2022.792875