Published in final edited form as:

Pediatr Phys Ther. 2014 ; 26(2): 191–199. doi:10.1097/PEP.0000000000000037.

Performance of High School Adolescents on Functional Gait and Balance Measures

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Abstract

Purpose—To describe the performance of high school adolescents during common functional gait and balance measures used in vestibular physical therapy.

Methods—A cross-sectional study of 91 participants determined their performance on the Activities - specific Balance Confidence (ABC) scale, Dynamic Gait Index (DGI), Functional Gait Assessment (FGA), Timed “Up & Go” (TUG), Five Times Sit to Stand (FTSTS) test, tests of gait speed (GS) and the Balance Error Scoring System. In a subset of this sample, GS, TUG, and the FTSTS were repeated twice to examine test-retest reliability.

Results—The measures of GS, TUG, and FTSTS were normally distributed. The ABC, DGI, and FGA exhibited a ceiling effect. The timed measures exhibited moderate to good reliability.

Conclusions—These performance scores may provide end points for discharge from vestibular physical therapy. However, clinicians should be aware of the ceiling effect exhibited by some measures.

Keywords

activities of daily living; adolescence; gait; motor skills; postural balance; reproducibility of results; vestibular function tests/standards

Introduction and purpose

The awareness of concussion in high school aged adolescents has increased substantially in the last decade. Many studies have noted that high school athletes are more susceptible to

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Conflict of Interest statement: The authors declare no conflict of interest

concussion compared with older athletes.¹⁻² Furthermore, high school athletes may have prolonged recovery compared to older athletes in the domains of neurocognition and symptom resolution.³⁻⁴ Memory function in college athletes has been reported to return to the level of matched controls by day 3 post-concussion whereas high school athletes required 7 days to return to normal memory function.³ Differences between children and adults in glutamate sensitivity, tolerance to biomechanical changes after injury and different psychosocial factors have been proposed to explain the different courses of recovery between children and older individuals who sustain concussion.⁵⁻⁷ The differential rate of recovery between children and adults led to a consensus that conservative management should be used with children post-concussion.⁸⁻⁹ One of the principles of conservative management includes not allowing the child to return to play until the student-athlete achieves baseline (i.e. pre-concussion) performance on tests of neurocognitive function. In cases where baseline performance measures do not exist, age-referenced normative scores for neuropsychological testing are used to help assist in making decisions about return to play.¹⁰⁻¹¹ Additionally, maturational changes in neurocognitive performance may dictate use of the age-referenced scores if baseline testing has not been conducted recently.¹²⁻¹³

Reports of dizziness and imbalance are prevalent in individuals who have had a concussion. Estimates of the prevalence of persistent dizziness after mild traumatic brain injury (mTBI) (i.e. concussion) varies between 1.2% to 32.5% depending on age group and time of follow-up.¹⁴⁻¹⁵ Persistent balance problems have also been reported after concussion.^{10,16} Vestibular rehabilitation is increasingly being used to manage dizziness and balance disorders resulting from vestibular system dysfunction.¹⁷⁻²² Previous studies have shown that vestibular rehabilitation may reduce dizziness and improve overall balance for individuals with head injury.²³⁻²⁴ Additionally, a recent report reported that children with dizziness and balance disorders after concussion appear to benefit from vestibular rehabilitation.²⁵

For individuals treated with vestibular rehabilitation after concussion, it is common for the physical therapist to employ a wide array of self-report and performance measures to track recovery and make recommendations regarding discharge or return to work or athletic participation.²⁵⁻²⁶ Many of the clinical decisions regarding the exercise initiation, progression or discharge from physical therapy are based on the scores obtained through gait and balance testing as well as presenting symptoms. Adolescents present a challenge for balance assessment because they are too old for common developmental motor scales such as the Bruininks - Oseretsky Test of Motor Proficiency (4.5–14.5 years).²⁷ Furthermore, there are no estimates of reliability or normative scores in other common outcome measures utilized in vestibular physical therapy that were developed for use in middle-aged and older adults, such as the Activities – specific Balance Confidence (ABC) scale,²⁸ the Dynamic Gait Index (DGI),²⁹ the Functional Gait Assessment (FGA),³⁰ gait speed (GS), the Timed “UP & GO” (TUG),³¹ and the Five Times Sit to Stand (FTSTS) test.³² By providing data about performance on gait and balance measures by this age group, clinicians will be able to quantify balance impairments in adolescents after concussion and will be able to make a better determination of when they are able to return to athletic participation after concussion. Therefore, the purpose of this study was to describe the performance and determine the

reliability of common clinical balance outcome measures in healthy adolescents between the ages of 14 and 18 years.

Methods

Design

A cross-sectional sample of students in the 9th through the 12th grades was obtained through local high schools. The study protocol was approved by the Institutional Review Board (IRB) at the University of Pittsburgh and by the school board of the participating schools. An invitation letter that described the purpose and procedures of the study was sent to parents. A total of 950 invitation letters were sent. Students who were 18 years old provided informed consent and students who were younger than 18 years of age provided assent after their parents provided informed consent.

Subjects

Ninety-one participants voluntarily enrolled from 3 local high schools in Allegheny County, Pennsylvania. Two of the schools were private single-gender parochial schools in an urban location (one female, and one male) and the other school was a public co-educational school in a suburban school district. The participants were excluded if they had a self-reported history of previous concussion or if they had a history of low back or lower extremity problems within 3 months prior to the date of testing. The demographic characteristics of participants (age in years, height, body mass) are summarized in Table 1. Participants were asked to report the duration of participation in formal athletic practice for their high school or club teams. Participants also reported the duration of their recreational physical activities.

Outcome measures

The ABC is a self-report questionnaire which was used to assess the participant's level of confidence that they would not lose their balance while performing 16 functional activities.²⁸ The highest possible score of 100 suggests maximum confidence and a score of 0 suggests no confidence.

The DGI is an 8 item instrument that assessed the participants' ability to walk over a course of 20 ft (6.1 m) on a level surface, walk with head turns, walk with pivot turns, changes of speed, over and around obstacles and up and down steps.²⁹ The scale for each item ranges from 0–3, where 0 means severe impairment and 3 indicates normal performance. The highest possible score is 24. Its concurrent validity has been established with the Berg Balance Scale in individuals with vestibular disorders.³³ DGI scores less than 19 are said to be correlated with reports of falls in community dwelling older adults and in individuals with vestibular disorders.

The FGA is a 10-item test based on the DGI.³⁷ The 3 new items introduced in the FGA were gait with a narrow base of support, gait with eyes closed, and ambulating backwards. The maximum score is 30. Higher scores indicate better performance. The FGA demonstrated concurrent validity with other measures used in vestibular rehabilitation ($r = .64$ to $.80$).³⁰

Gait speed was recorded while participants ambulated at their comfortable speed over 4 meters using a standing start and over 6.1 m using a walking start. Test-retest reliability of comfortable gait speed usually is above 0.90 for different participant populations.^{38–39} The participant was instructed to “Walk to the other end of the course at your usual speed passing the marked line, just as if you are walking down the street to go to the store.” The timing started when the first foot crossed the start line, and ended when the first foot crossed the stop line.

The TUG is a timed test during which the participant stands from a chair, walks 3 meters at his/her normal walking speed, returns to the chair and sits down.³¹ The participants were instructed as follows: “When I say start, I want you to stand and walk at your usual speed to the tape on the floor, and then come back and sit in the chair.” The timing began when the examiner said “start” and ended when the participant’s buttocks touched the chair. The TUG has been widely used in vestibular rehabilitation studies.^{40–43} Slower TUG scores (>11.5 sec) are said to be correlated with reports of falls in individuals with vestibular disorders.^{35, 44}

The FTSTS test requires participants to stand-up and sit down from a chair (43 cm high), 5 times as quickly as possible. The participants completed the task with their hands crossed on their chest.³² The instructions were: “I want you to stand up and sit down 5 times as quickly as you can when I say “GO”. Stand up fully during each time. Do not touch the back of the chair during each repetition. Keep your hands crossed on your chest.” The timing period began when the examiner said, “GO” and ended when the participant’s buttocks touched the chair on the 5th repetition. The FTSTS test exhibited moderate correlation with gait and dynamic balance measures in patients with vestibular disorders.⁴⁵ The discriminative and concurrent validity of the FTSTS test have been reported in patients with vestibular disorders.⁴⁶

The Balance Error Scoring System (BESS)⁴⁷ is a component of the Sport Concussion Assessment Tool 2, recommended in the Consensus Statement on Concussion in Sport.⁸ The BESS requires participants to maintain balance with eyes closed with their hands on their iliac crests under 6 different conditions⁴⁷: 1) firm surface, feet together, 2) firm surface, single leg stance, 3) firm surface, tandem stance, 4) foam surface, feet together, 5) foam surface, single leg stance, and 6) foam surface, tandem stance. Each trial was 20 seconds.⁴⁷ The scores were calculated by counting the total number of errors. Errors could be any of the following: 1) hands lifted off the iliac crests, 2) opening eyes, 3) a step, stumble or fall, 4) moving the hip into >30 degrees of abduction or flexion, 5) lifting the forefoot or heel, or 6) remaining out of the test position for > 5 seconds. The maximum number of errors in each trial was 10 and the maximum number of errors in total was 60.⁴⁷ A systematic review has concluded that the BESS demonstrated moderate to good reliability and correlated well with other measures of balance using testing devices. Although the review included high school athletes and community dwelling adults, the majority of the participants included in the review were college athletes.⁴⁸

Procedure

After the demographic and athletic participation information was recorded, participants completed the ABC. Participants then went to 1 of 3 stations where the tests were performed: 1) GS, TUG, and FTSTS, 2) DGI/FGA, and 3) the BESS. Participants performed the testing in a pseudo-random order based on test station availability. The same examiner conducted two consecutive trials of gait speed, TUG, and FTSTS. In a sample of 61 participants who were examined by one of the raters, the two consecutive trials were used to calculate the test-retest reliability for the gait speed, TUG and FTSTS. Seven raters who were licensed physical therapists and routinely administered the tests participated in DGI/FGA scoring, and six physical therapy graduate students (PhD students) participated in the scoring of GS, the TUG and the FTSTS. Reliability training was provided to all examiners before the testing started and the differences in timed tests between examiners was 0.1 sec. In a subset of the high school students ($n = 23$), an electronic timing device was used to record gait speed so that validity of the therapist administered gait speed could be determined.

The BESS performance was videotaped for later scoring using a camera placed 3 meters from the participants, perpendicular to the frontal plane in quiet standing. The participant was facing the camera while performing the 6 different conditions. Inter-rater reliability was examined using 2 Doctor of Physical Therapy student raters who were provided with written instructions and trained to score the BESS. To minimize bias, the 2 raters did not consult each other during the rating.

Statistical analysis

Statistical analyses were conducted to determine any associations between the subject demographic variables and the outcome measures. Data were tested for normality using the Komolgorov-Smirnov test. An independent t-test was performed to examine for an effect of gender or athletic participation on the normally distributed scores. A Mann-Whitney U test was used to examine the effect of gender or athletic participation on the non-interval measures of ABC, DGI, FGA and the total BESS score. Correlation analyses were performed to examine the relationship between height, body mass, and the performance of gait and balance measures. Pearson correlation coefficients were calculated for normally distributed variables, and the Spearman correlation coefficients were calculated for variables not normally distributed.

For the total score of each outcome measure, scores were calculated at the 5th, 25th, 50th, 75th, and 95th percentiles. In addition, percentile scores were calculated for the individual items of the ABC, DGI and FGA. To determine reliability of GS, TUG and FTSTS, the intraclass correlation coefficient (ICC) was computed using the 2-way mixed model for single measures (3, 1). From the ICC analysis, the 95% confidence interval, the standard error of measurement (SEM) and minimal detectable change (MDC) were calculated. The validity of clinician administered gait speed was tested against the electronic timing device by computing the ICC, using the 2-way mixed model for single measures.

The inter-rater reliability of the total BESS score was examined by using the 2-way mixed ICC model (random subjects, fixed raters, absolute agreement). Percent agreement, expected agreement and weighted kappa were calculated for the 6 individual conditions. For all analyses, the Statistical Package for the Social Sciences (SPSS version 20) was used (SPSS Inc., Chicago IL).

Results

Of the 108 participants who consented, 17 were excluded from the study due to previous history of concussion or a recent lower extremity injury. Ninety-one adolescents participated in the study (47 M/44 F). The majority of the participants (65% (60/91)) were younger than 16 years old (Table 1). Twenty-nine percent of the participants were not involved in any formal athletic participation. For the participants who were involved in formal athletic participation, cross country running was the most common sport (11 participants), followed by basketball (n=9), soccer (n=7) and volleyball (n=7). The most common duration of formal practices was 3 hours per week (9 participants), followed by 2 hours per week (8 participants). However, the median was 7 hours per week (range: 1–27 hours). An independent t-test was performed to examine if the participants with no formal practice were significantly different in the performance on any of the administered measures. The results demonstrated that the group with no formal athletic performance had significantly worse scores on the FTSTS ($M = 8.1$, $SD = 1.4$ s) compared with the group with formal athletic practice ($M = 7.3$, $SD = 1.3$ s), ($t_{89} = 2.4$, $P = .016$).

No significant differences were found between males and females except for the ABC where male participants exhibited higher scores ($M = 95$, $SD = 5$) compared to female ($M = 92$, $SD = 7$), ($U = 762$, $P = 0.03$). No significant correlations were found between height, weight and any of the administered measures.

The percentile reference scores for the ABC, DGI, FGA, TUG, GS (4m & 6.1 m) and FTSTS are detailed in Table 2. The distributions of timed performance tests of the TUG, GS and FTSTS were normal and did not exhibit ceiling or floor effect. Additionally, the percentile score for gait speed measured over a course of 4 m and 6.1 m revealed that walking speed was generally faster when tested over the course of 6.1 m (walking start). A ceiling effect was observed with the ABC, DGI, and FGA outcomes as demonstrated by the similarity of the scores from 50th to 95th percentile. Table 3 demonstrates this effect in more detail by listing scores for the individual items of the ABC. A full confidence score of 100 was rated by 75% of the participants for 6 items, and by 50% for an additional 5 items. A closer inspection of the individual items of the ABC revealed that the question “Walk outside on icy sidewalks?” and “Step onto or off an escalator while you are holding onto parcels such that you cannot hold onto the railing?” were the 2 items on the ABC scale in which subjects had the least confidence in performing.

The DGI also demonstrated a ceiling effect in which the full score (24/24) was achieved by more than 50 percent of the participants. To a lesser extent, the FGA also exhibited a ceiling effect in which the optimal score was achieved by at least 25 % of the participants. The FGA percentile scores revealed that gait with eyes closed was the most difficult item; the 5th

percentile scored a 0, 25th percentile scored a 2, and the 50th percentile scored a 3. A score of 3 (full score) was achieved for all other items at the 25th percentile (Table 4).

The BESS test demonstrated variability in scores depending on the 6 conditions (Table 5). The condition of single leg stance on foam surface was the most difficult condition, followed by the conditions of single leg stance on a flat surface and tandem stance on a foam surface in which these 2 items were almost equally difficult. Stance with feet together exhibited a ceiling effect in which the majority of participants did not commit any errors except a few participants who had 1 error while the task was performed on the foam surface.

Reliability analysis

The test-retest reliability for gait speed, TUG and FTSTS (n = 61) with 95% confidence interval, SEM and MDC are summarized in Table 6. Gait speed measured over the course of 6.1 m using a walking start exhibited similar values for reliability coefficient, SEM and MDC compared to gait speed measured over a course of 4 m using a standing start. The ICC for clinician administered gait speed vs. electronic timing was 0.98 with 95% CI (0.95 – 0.99).

The percent agreement and weighted kappa statistics for the BESS are summarized in Table 5. The inter-rater reliability for the total score was 0.95. Weighted kappa statistics could not be calculated for the condition with feet together on a firm surface due to the lack of variability between raters. For the other 5 conditions, the weighted kappa scores ranged between 0.46 and 0.79.

Discussion

The results demonstrated that GS, TUG, and FTSTS are reliable measures to assess gait and balance performance in adolescents. Although the ABC, DGI and FGA exhibited a ceiling effect in this healthy young population, the distributions of the timed tests of GS (4 m & 6.1 m), TUG, and FTSTS did not exhibit a ceiling or floor effect, and therefore these timed tests can be useful in tracking the recovery of gait and balance deficits in individuals between age of 14 and 18 years. In addition, the inter-rater reliability of the BESS is excellent when performance is video-recorded and scored at a later time.

Review of the percentile scores revealed that the ABC, DGI and FGA had a ceiling effect, which may limit their usefulness in this population. A potential alternative to using the full ABC is to use the recently evaluated ABC-6 questionnaire, an abbreviated version of the full ABC that includes item numbers 5, 6, 13, 14, 15, and 16 and is suggested to have psychometric properties analogous to the full ABC questionnaire.⁴⁹ A closer look at the individual items of the ABC in the current study revealed that the items included in the ABC-6⁴⁹ exhibited lower scores and had more variation than other items in the full version of ABC. However, a validation study is needed before a recommendation is made to adopt the use of an abbreviated version over the full version of ABC.

The performance measures of the DGI and FGA also exhibited a ceiling effect, suggesting that these tests do not assess higher-level balance abilities that adolescents in this age range

may possess. Since the FGA has less of a ceiling effect compared to DGI in this age group, the use of the FGA is recommended over the DGI. These findings emphasize the importance of using comprehensive assessment measures; this conservative approach is in line with the recent recommendations on concussion management endorsed by the National Athletic Trainers Association and the 3rd International Conference on Concussion in Sport.^{8–9}

No other reference scores are available for the DGI in the age range examined in this study. One study provided age-specific reference values for the FGA;⁵⁰ the study included community dwelling older adults between the ages of 40 and 89 years and provided reference values for each decade. The study did not include participants younger than 40 years based on the assumption that FGA performance is not expected to decline with age until middle age or later. The mean score and range obtained for the participants between 40 and 49 years was 29 years (range 24–30) which matches the median score and range obtained in this study.⁵⁰ The item of ambulating backward was reported to be the most difficult item in this study and in the study of Walker et al.⁵⁰ A comparison of the performance on individual items revealed that a full score of 3 was achieved by more than 50% of participants for all items. However, participants between 40 and 49 years old exhibited average scores that were less than 3 on the 3 items gait on level surface, gait with eyes closed, and ambulating backwards.

Examination of the percentile scores showed that gait speed was faster when measured over 6.1 m compared with 4 m, which can probably be explained by the difference in the initiation of movement. Over the course of 4 m, the participants initiated walking at the start line. However, over the 6.1 m course, walking was initiated 1 meter before the starting line. This difference in walking speed between the 2 methods suggests that clinicians should be consistent with their method of administration of gait speed and use the appropriate norms. A previous study established reference scores for participants that were similar to age range presented in this manuscript.⁵¹ However, the previous reference values were provided separately for male and female participants. This is contrary to the findings of this study that there was no gender effect on gait speed in this age range. Nonetheless, the median gait speed of the 6.1 m reported in this study (1.32 m/sec) is consistent with the means provided for males (1.35 m/sec) and females (1.24 m/sec) between 15 and 19 years old.⁵¹

The difference in the FTSTS scores between participants who were involved in formal athletic practice and those who are not involved in athletic practice was unexpected, given the lack of differences in the other measures. The participants were instructed to perform the task as quickly as possible; therefore, participants with formal sports practices may have demonstrated better functional lower extremity strength, which is known to affect repetitive sit to stand performance, when compared with participants with no formal athletic involvement.⁵² Exploring the differences in FTSTS scores between athletes and non-athletes and across different sports would be of interest. However, this goal was unattainable with the limited number of participants in each sport category. On the other hand, GS and TUG may not have been significantly different between athletes and non-athletes since they were performed at the participants' "usual" walking speed compared to maximal speed in the FTSTS. While the FTSTS may have assessed functional lower extremity strength and therefore, resulted in significantly better performance for athletic population, GS and TUG

may not be challenging enough to be able to sort out higher functional differences between athletes and non-athletes. Nonetheless, they can still be important outcome measures because if a participant has an abnormal score on such a low-level test, then it is likely that he/she would not be cleared for return to play. If a normal score was achieved, it would form just one criterion on the decision to return to play.

The absence of a relationship between gender, height and body mass with most of the administered measures may be a reflection of the limited range of scores achieved with these measures. The absence of a relationship may also suggest the reference values provided through this report can be used for all individuals in this age range.

The distribution of total BESS scores appear to be similar to several previous studies of high school and college-age subjects that have examined BESS performance in the context of differentiating athletes with and without concussion and also for different sports.^{53–58} The median number of errors accumulated in this age group (13 errors) compares well to the average number of errors accumulated in high school and collegiate athletes without history of concussion (range 12 to 13 errors).^{47, 54, 56–58} One benefit of the current study is that it also provides percentile values for each of the individual conditions in the BESS. Compared with previous studies of high school aged subjects,^{56, 59} the median values of the individual conditions are similar to the average values of the previous studies, except for the single leg stance on foam condition, which had a higher number of errors in the current study (7 vs. 4 to 5). Differences in reference values of the BESS across the different studies can be attributed to several factors, including inherent differences in balance performance across different age ranges and sport abilities, disparate scoring methods, rater experience, and participant learning effects. Regarding balance abilities of different sports, female gymnasts accumulated an average of 9.1 errors, female collegiate soccer players had 12.5 errors, and female basketball athletes accumulated 14.1 errors.⁵⁵ Clinicians who intend to use these scores are encouraged to consider the limitations of these reference values and are encouraged to consider the degree to which their patients match the participants included in this study.

The selection of the outcome measures used in this manuscript was based on their wide use in balance clinics. Although the Sensory Organization Test (SOT, Neurocom, Inc.) may offer more in-depth information for subtle balance deficits found in adolescents, access to posturography is limited for patients at most clinics because of its high cost. Other clinical balance measures such as the Fullerton Advanced Balance (FAB) Scale may offer a unique insight about balance deficits.⁶⁰ However, similar to several of the tests used in the current study; the FAB was developed for use in older adults who are capable of community ambulation. The 10 items of the FAB are comparable to the items in the DGI and FGA, and therefore, would be expected to demonstrate the same ceiling effects in the adolescent population. Due to the overlap between the FAB items and other measures included in this study, the FAB test was not examined in this study.

Reliability analysis

The reliability for the timed measures examined in this study (GS, TUG, and FTSTS) ranged between 0.79 and 0.91, suggesting that these measures have moderate to good reliability and

can be used during vestibular rehabilitation for this age group. For the FTSTS, the ICC score reported in the present study [0.91 (95% CI 0.86 – 0.95)] falls in the wide range of reliability coefficients previously reported in other populations (0.64 – 0.99).^{32, 61–65} Test-retest reliability of TUG and GS were lower in this group of adolescents than what has been published for older adults. Reliability of the TUG generally is greater than 0.9,^{31, 66} although the reliability has been reported as low as 0.5.⁶⁷ Similarly, reliability of gait speed has been reported at 0.9 and above.^{39,66} Why adolescents have lower test-retest reliability for walking speed demonstrated by the GS and TUG measures is not clear.

Although the range of scores obtained for this sample of adolescents is limited compared with other populations that have been examined, it is representative of the healthy adolescent population. Furthermore, the relatively large size of the MDC would not preclude timed measures from being used as a measure of change. For each of the timed measures, if a patient initially had an abnormal value (i.e. 5th percentile), achievement of the MDC would raise the patient to 25th percentile, which is a reasonable improvement.”

The inter-rater reliability ICC for the total BESS score was 0.95. This score is higher than inter-rater reliability scores previously reported. McLeod reported an inter-rater ICC score of 0.85 in a sample of female high school basketball players.⁵⁶ whereas the inter-rater reliability scores for individual conditions have ranged from 0.78 to 0.96.⁴⁷ However, Finnoff et al have reported an ICC score of 0.57 in a sample of 30 college athletes.⁶⁸ Several reasons may have contributed to the differences in inter-rater reliability reported among the studies. The sample size of 91 participants in this study was much higher than the other 2 studies, which may suggest that the previous studies were underpowered; in McLeod et al study,⁵⁶ although the overall sample consisted of 62 participants, the analysis of inter-rater reliability was conducted only for a subset of this sample and no further demographics details were provided for the reliability subset.⁵⁶ The other study by Finnoff et al. included a sample size of 30 participants that were examined by 3 raters.⁶⁸ The balance abilities of the participants may also have played a role. Participants in this study were different than participants reported in other studies, in which participants were described as “athletes” with no further description,⁶⁸ while another study consisted of female basketball players.⁵⁶ However, our study included athletic and nonathletic male and female participants. This may have led to larger variability in scores and improved the ICC value. Additionally, the raters in this study scored the BESS performance by viewing a videotape; this is contrary to McLeod et al. in which the BESS was scored by direct observation.⁵⁶ Although Finnoff et al have used videotapes for scoring,⁶⁸ their ICC score was much lower than the ICC presented in this manuscript. If the self-selected pace of viewing the videotapes used in this study improved the reliability is unclear, whereas in the Finnoff et al’s study the examiners were asked to score 30 participants consecutively in the same session and therefore, fatigue may have resulted in less accurate scoring.

Due to recruitment difficulties for students in the upper grades of high school, the majority of participants in this study were 14 and 15 years old. In addition, the participants in this study were students from private and suburban schools in 1 geographic area. They may represent a specific socioeconomic status (SES) and may not be reflective of the wide spectrum of high school aged adolescents.

Conclusion

These preliminary performance scores provide a reference for interpreting the performance of common functional gait and balance measures for individuals between 14 and 18 years of age who require vestibular/balance rehabilitation, such as individuals who sustain concussion. Although this report emphasized the clinical relevance of these findings to concussion management, the balance measures examined in this study can be used for balance assessment in patients with conditions other than concussion (e.g. orthopedic injuries, developmental coordination disorder). Therefore, clinicians are encouraged to incorporate the findings of this study in assessment of balance problems across different diagnoses.

These performance scores may quantify balance problems in adolescents seen for vestibular physical therapy. However, clinicians should be aware of the ceiling effect exhibited by some measures. The inclusion of participants who do not participate in athletics makes the reference scores presented in this manuscript applicable for both athletes and non-athletes who might be susceptible to mTBI.

Acknowledgments

We would like to thank the graduate students from the University of Pittsburgh and the physical therapists from the Centers for Rehabilitation Services of the University of Pittsburgh Medical Center for assisting in the data collection, and students from Quaker Valley, Oakland Catholic and Central Catholic High Schools for participating.

We would like to thank the Clinical and Translational Science Institute (CTSI) at the University of Pittsburgh for help in the recruitment of subjects, and the Department of Physical Therapy at the University of Pittsburgh for providing the equipment for testing.

Grant support: The National Institutes of Health through Grants Number UL1 RR024153 and UL1TR000005 supported the project described.

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Table 1

Demographic Characteristics of Participants.

	Male	Female
Number of participants (n)	47	44
Age in years, mean (SD)	15.5 (1.1)	15.7 (.9)
Mass in kg, mean (SD)	66 (17)	61 (11)
Height in cm, mean (SD)	172 (10)	166 (6)
Participation in formal sports	Yes: 34 No: 13	Yes: 31 No: 13

Table 2

Percentile Scores for the Outcome Measures (n = 91).

	Percentile				
	5	25	50	75	95
Activities – specific Balance Confidence Scale	79	91	95	98	99
Dynamic Gait Index	22	23	24	24	24
Functional Gait Assessment	26	28	29	30	30
Gait speed over 4m (m/sec) Standing start	0.84	1.09	1.19	1.29	1.46
Gait speed over 6.1 m (m/sec) Walking start	1.03	1.23	1.32	1.44	1.69
Timed “UP & GO” (sec)	6.1	6.9	7.5	8.3	9.3
Five Times Sit to Stand (sec)	5.4	6.7	7.5	8.4	9.8

Table 3

Percentile Scores for Individual Items on the Activities-specific Balance Confidence (ABC) Scale (n =91).

Activity	Percentile				
	5	25	50	75	95
<ul style="list-style-type: none"> • Walk around the house • Reach for a small can off a shelf at eye level • Walk outside the house to a car parked in the driveway • Walk across the parking lot to a mall 	90	100	100	100	100
<ul style="list-style-type: none"> • Sweep the floor • Walk up or down a ramp 	80	100	100	100	100
<ul style="list-style-type: none"> • Walk up and down the stairs • Bend over and pick up a slipper from in front of a closet door • Get into or out of a car? 	80	90	100	100	100
<ul style="list-style-type: none"> • Walk in a crowded mall where people rapidly walk past you • Step onto or off of an escalator while you are holding onto a railing 	70	90	100	100	100
<ul style="list-style-type: none"> • Stand up on tip toes and reach for something above your head • Stand on a chair and reach for something 	70	80	90	100	100
<ul style="list-style-type: none"> • Are bumped into by people as you walk through the mall 	60	80	90	100	100
<ul style="list-style-type: none"> • Step onto or off an escalator while you are holding onto parcels such that you cannot hold onto the railing 	50	80	90	100	100
<ul style="list-style-type: none"> • Walk outside on icy sidewalks 	40	70	80	90	100

Table 4

Percentile Scores for Individual Items on the Functional Gait Assessment (FGA).

	Percentile				
	5	25	50	75	95
• Gait with eyes closed	0	2	3	3	3
• Gait with vertical head turns					
• Gait and pivot turn	3	3	3	3	3
• All other FGA items*	2	3	3	3	3

* Gait Level surface, Change in gait speed, Gait with horizontal head turns, Step over obstacle, Gait with narrow base of support, Ambulating backwards, Stair climbing

Table 5

Percentile Scores, agreement and reliability for the Balance Error Scoring System (BESS). Lower scores indicate better performance on the BESS.

	Percentile					Agreement* and reliability†
	5	25	50	75	95	
Firm surface, feet together	0	0	0	0	0	‡
Firm surface, single leg stance	0	1	2	4	7	0.77*
Firm surface, tandem	0	0	0	1	4	0.79*
Foam surface, feet together	0	0	0	0	1	0.46*
Foam surface, single leg stance	2	5	7	10	10	0.68*
Foam surface, tandem	0	1	3	4	7	0.72*
Total BESS scores	4	10	13	18	24	0.95‡

* Agreement is measured via weighted kappa (kw)

† Weighted kappa (kw) could not be calculated because scores did not vary.

‡ Two-way Mixed Intraclass correlation coefficient (3,1)

Table 6

Reliability Coefficients, Standard Error of the Measurement (SEM), and Minimal Detectable Change (MDC) for the Timed Measures (n = 61).

	ICC (95 %CI)	SEM	MDC
Gait speed (4 m)	0.81 (0.71 – 0.88)	0.07 m/sec	0.18 m/sec
Gait speed (6.1 m)	0.79 (0.67 – 0.87)	0.07 m/sec	0.21 m/sec
Timed “UP&GO”	0.84 (0.75 – 0.90)	0.3 sec	0.9 sec
Five Times Sit to Stand	0.91 (0.86 – 0.95)	0.1 sec	0.4 sec