Acta of Bioengineering and Biomechanics
Vol. 19, No. 2, 2017

Original paper
DOI: 10.5277/ABB-00675-2016-02

Evaluation of the accuracy of the postural stability measurement with the Y-Balance Test based on the levels of the biomechanical parameters

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Purpose: The study of dynamic balance involves tests that assess the muscle control of spatial changes of the position of the centre of gravity over the base of support. The purpose of this work was to determine the structure of the Y-balance test and its accuracy based on the measurements of strength performance of the muscles acting on the knee joint as well as the flexibility and balance in boys aged 14 years. *Methods*: The study included 43 schoolboys regularly participating in physical education lessons. The examination of postural stability was conducted with the use of the Y-balance test. The measurements of muscle strength and of resistance to fatigue of the extensors and flexors of knee joints in isometric contraction were performed on a measurement stand in a standard position with the use of tensometric sensors. The measurement of mobility range of the lower extremity joints was performed according to the SFTR. The examination of balance was performed with the use of the modified "Flamingo balance test". *Results*: The factor structure of the Y-balance test results for the left and right lower extremities is similar and includes five principal independent factors that characterise the structure of analysed variables. They explain 76% and 74% of communality in total for the left and the right extremity, respectively. *Conclusions*: The extracted factor structure points to a hybrid structure of the Y-Balance Test and shows its accuracy in the measurements of the lower limb joint mobility and strength performance of knee joint extensors.

Key words: *biomechanics, motor control, postural stability, Y-Balance Test, structure test*

1. Introduction

The term 'postural stability' refers to the ability to regain the state of balance owing to correct analysis of afferent information and adequate efferent response to the control trunk and the lower limb muscles. Control of the position of the centre of gravity over the base of support is essential here [1]. The term "balance", in turn, is synonymous to posture control and refers to processes that allow for maintenance of postural stability. These terms are frequently used interchangeably in the literature [2]. The investigators assess most frequently postural stability to evaluate the risk of falls and body injuries related to them or the deficits resulting from them or to evaluate the efficacy of the treatment conducted or to predict the time needed for return to sport or recreational activities [3]–[5].

Postural stability is examined both in static positions, such as standing on both legs or on one leg, when declinations of the body's gravity centre projection beyond the quadrangle of support are assessed, and in dynamic conditions when ability to maintain balance in situations of changing position of the point of support is measured. Testing of dynamic balance involves tests that assess muscle control of spatial

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Received: June 17th, 2016
Accepted for publication: January 16th, 2017

changes of the position of the centre of gravity over the base of support. The Y-Balance Test (YBT) is one of the most popular research tools used for assessment of dynamic postural stability [6]. It is used worldwide in examinations of competitors practicing various disciplines of sport and recreation. It was used for testing of postural stability of soccer players, basketball players, gymnasts and cricket players [7], [8]. A common injury in many sport disciplines is talocrural joint sprain which frequently results in instability of this joint. Its incidence for all sport disciplines ranges from 15 to 20% [9]. According to studies by many authors, in sportspeople who had experienced talocrural joint sprain postural stability measured with the YBT was decreased in the majority of cases [10]–[12].

Some authors evaluated the YBT reliability in their publications but only few of them addressed the structure of this test [4], [13]. Confirmation of relationship of YBT results with strength, balance or flexibility was found in less than ten publications [14], [15]. As the YBT is used more and more frequently in various studies, it seems necessary to try to answer the question: what aspects of human motility are actually measured by this test? It is related directly to determination of the level of accuracy of the test which – along with reliability, standardisation, objectivisation and normalisation – renders it a valuable diagnostic tool. The most desired test for population studies is a test that would measure a single parameter of human motility. High hybridity of the test may limit inference possibilities and decrease the level of accuracy of the test.

The purpose of this work was to determine the structure of the YBT and its accuracy based on the measurements of strength performance and resistance to fatigue of the muscles acting on the knee joint in static conditions, as well as flexibility and balance in boys aged 14 years who do not practice professional sports but regularly participate in physical education lessons.

2. Materials and methods

Subjects

The study included 43 boys aged 14 years, pupils of Gimnazjum No. 2 (secondary school) in Skawina near Kraków, Poland. The examined boys regularly participated in physical education lessons, 8 didactic hours per week. The tests were conducted during the morning hours in June 2015 in the sports hall. The tests were non-invasive and were performed with the school's permission and with the consents of the parents of the examined children. The scope of the tests and examinations did not go beyond standard prophylactic examination within the physical education curriculum for secondary school adolescents and was accordant with the Declaration of Helsinki issued by the World Medical Association [16].

Table 1. Participant characteristics

	Age (year)	Height (cm)	Body weight (kg)
$\bar{x}$	13.90	171.50	60.00
SD	0.29	7.39	10.76

Data collection and analysis

At the start of the test body height and weight of the participants were measured and additionally, diagnosis of lateralisation was performed with the 'step forward' test [17]. Only the right-legged subjects were qualified for further study. Examination of postural stability was conducted with the use of the Y-Balance Test. A measurement procedure was defined in accordance with Plisky et al. [4] and Shaffer et al. [13] guidelines. Three trials were done for each lower extremity and for each movement direction. If the test was started from the left lower extremity the subject performed the first three trials standing on the left lower extremity and reaching forward (anterior reach) with the right lower extremity. In the next three trials the right lower extremity was the stance extremity and the left one – the reach extremity, with the same reach direction. This trial mode was repeated with measurements for the posteromedial and posterolateral directions. The measurements of the distance of the indicator moved from the central platform were done with accuracy to 0.5 cm. The trial was deemed successful when the subject was able to return to the starting position after he had performed the movement. After the test was completed, relative lengths of both lower extremities were measured with accuracy to 0.5 cm. During the analysis of the results the highest achieved reach result in each direction during unilateral stance was corrected for the length of the stance extremity, according to the following formula:

$$MAXD\,(\%) = [EL/LL] \times 100. \tag{1}$$

Composite YBT score was also calculated for each subject, using the following formula:

$$YBT\text{-}CS\,(\%) = [(AN + PM + PL)/(LL \times 3)] \times 100, \tag{2}$$

where: $MAXD$ (%) – the maximum reach distance in one direction in %, EL – distance of reach in one direction, *LL* – relative length of the extremity, *YBT-CS* (%) – YBT composite reach score, *AN* – anterior reach, *PM* – posteromedial reach, *PL* – posterolateral reach.

Measurements of muscle strength and resistance to fatigue of extensors and flexors of the knee joints in isometric contraction were performed on a measurement stand in a standard position with the use of tensometric sensors (Fig. 1). Muscle strength measurements were carried out in a measuring stand equipped with a Hottinger tensometric sensor (accuracy: 0.5%)

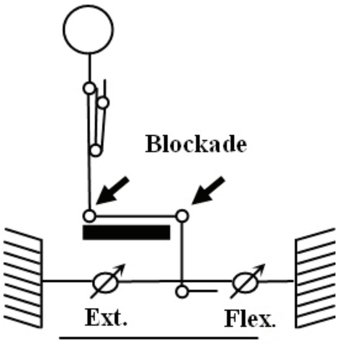

Fig. 1. Standard position for measurement of strength and resistance to fatigue of extensors and flexors of the knee joints

Based on the recorded maximum strength, the maximum (3) and relative (4) muscle torques for knee joint flexors and extensors were calculated. Due to the fact that the values of relative torques were standardised values that eliminated the effect of the body weight on strength performance, this variable was used in the further analysis of the results.

$$\tau_{\max} = F_{\max} * d, \tag{3}$$

where: $\tau_{\max}$ – the maximum torque in the tested muscle group [Nm], $F_{\max}$ – the maximum force developed during isometric contraction in the tested muscle group [N], d – the moment arm for the external force (the distance from the biomechanical rotation axis in the joint to the line of the dynamometer) [m].

The relative values of torques were calculated from the formula:

$$\tau_r = \tau_{\max}/m \tag{4}$$

where: τ_r – the relative torque [Nm/kg], m = body mass of a subject [kg].

Measurements of resistance to fatigue were carried out in the same standard position. The trial aimed to achieve the maximum level of strength and maintain it for 20 seconds. The coefficient of regression of the force (CRF) calculated according to formula (5) was the measure of resistance to fatigue.

$$CRF = (F_{\max} - F_{\min})/t, \tag{5}$$

where: $F_{\max}$ and $F_{\min}$ – the maximum and minimum force developed during isometric contraction in the tested muscle group [N], t – the effective time of muscle group contraction.

A measurement of range of motion of the lower extremity joints was performed according to the SFTR methodology with a Bosch electronic goniometer with accuracy to 1° [18]. Extension, flexion, abduction, adduction and external and internal rotation were measured in the hip joint, flexion – in the knee joint, and dorsal and plantar flexion – in the ankle joint.

An examination of balance was performed with the use of the modified single leg balance test – "Flamingo balance test" [19]. The measurement method was modified from the original test version. The subjects performed two trials for each extremity. The time was measured within 1 second's accuracy. The time was measured until the moment of balance loss (touching the ground with any part of the body). The better time result was entered into the test result form.

Statistical analysis

At the initial stage of statistical analysis, a preliminary selection of variables for factor analysis was done. Variables that were not interrelated with mathematical relationships were selected. A factor analysis was performed with the use of the method of principal component analysis (PCA) based on correlation matrix. The number of extracted factors was determined by the highest possible communality explaining factor structure variability and by the possibility of their substantive interpretation. The analysis included varimax factor rotation to maximise the variance of baseline variables.

3. Results

Tables 2 and 3 present the extracted factor structure of the variables characterising the obtained YBT results for the left and right lower extremities.

The number of variables obtained as a result of the measurements and calculations appeared to be excessive. This excess was the result of mathematical relationships between some variables and thus of high correlation coefficients. For this reason indices of maximum muscle torques were removed from the analysis and relative muscle torques standardised for the body mass were left as a more objective representation of strength performance of the subjects. Interpretation of the factor analysis was also disturbed by an excessive number of variables describing joint ranges of motion in particular planes. Therefore, the representative total ranges of motion in hip, knee and ankle joints were selected for the analysis, as well as the sum of mobility of all examined joints.

Table 2. Factor structure of the results of the left lower extremity YBT determined with PCA (varimax rotation)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
FBT_L	0.14	–0.26	0.16	0.04	0.48
Y-ANT_L	0.42	–0.38	0.30	–0.29	–0.19
Y-POST-MED_L	0.71	–0.33	0.18	–0.27	–0.31
Y-POST-LAT_L	0.62	–0.49	0.30	–0.31	–0.25
Y-CS_L	0.70	–0.46	0.29	–0.33	–0.30
ROM_HKA_L	0.68	0.19	–0.54	0.25	0.01
ROM_H_L	0.42	0	–0.50	0.60	–0.25
ROM_K Flex_L	0.54	0.32	–0.41	–0.2	0.01
ROM_A_L	0.44	0.23	–0.04	–0.42	0.50
ROM_HKA_R	0.75	0.35	–0.42	–0.19	0.11
ROM_H_R	0.68	0.16	–0.41	0.02	–0.1
ROM_K Flex_R	0.56	0.14	–0.50	–0.17	–0.1
ROM_A_R	0.31	0.52	0.02	–0.39	0.55
CRF Ext_L	–0.19	0.34	–0.16	0.02	–0.24
τr EXT_L	0.60	–0.06	0.45	0.52	0.16
CRF Flex_L	–0.07	0.65	0.29	0.04	–0.31
τr Flex_L	0.44	0.33	0.75	0.20	0.01
τr Ext_L/Flex_L	0.13	–0.49	–0.53	0.38	0.16
CRF Ext_R	0.07	0.47	–0.04	0.21	–0.25
τr EXT_R	0.62	–0.02	0.43	0.53	0.19
CRF Flex_R	–0.04	0.77	0.09	–0.07	–0.27
τr Flex_R	0.46	0.44	0.53	0.27	0.08
τr Ext_R/Flex_R	0.15	–0.58	–0.19	0.24	0.08
Share of variance	0.26	0.18	0.14	0.11	0.70

FBT – "Flamingo balance test"; Y-ANT – Y-anterior; Y-POST-MED – Y-posteromedial; Y-POST-LAT – Y-posterolateral; Y-CS – Y-composite score; ROM – range of motion; Flex – flexion; Ext – extension; CRF – the coefficient of regression of force; *τr* – relative muscle torque; H – hip; K – knee; A – ankle; L – left; R – right.

The extracted factor structure for variables containing the YBT result for the left lower extremity includes five essential independent factors characterising the structure of the analysed variables that are substantively explainable. They explain 76% of communality in total.

Factor 1, explaining 26% of variance of the variables, is loaded on by the variables characterising the YBT results and ranges of motion of the hip and knee joints of the right extremity (ROM_H_R, ROM_K Flex_R), mobility of the left knee joint (ROM_K Flex_L), total mobility of joints of the right lower extremity (ROM_HKA_R) and relative muscle torques of knee joint extensors of both knee joints (*τr* EXT_L, *τr* EXT_R). Factor loading values of the variables ranged from $r = 0.54$ to $r = 0.75$. Total mobility in the joints of the right extremity (ROM_HKA_R) and YBT results show the highest correlation with the factor. The Y-ANT_L variable showed slightly lower factor loading ($r = 0.42$) compared to all the other YBT results.

Factor 2 explaining 18% of communality includes markedly lower values of factor loadings with respect to YBT results. This factor is loaded on most strongly by the variables that describe the results of the test of resistance to fatigue of flexors of both knee joints (CRF Flex_L, CRF Flex_R). The values of factor loadings captured by this factor are $r = 0.65$ and $r = 0.77$, respectively. Additionally the factor structure includes also the variable that determines the ratio of relative muscle torques of extensors to those of flexors of the right extremity (*τr* Ext_R/Flex_R, $r = –0.58$) and total range of motion in the ankle joint of the right extremity (ROM_A_R, $r = 0.52$). The variables listed above correlate on the mean level with the Y-POST-LAT_L ($r = –0.49$) result. Domination of relative torques of knee extensors over those of knee flexors is the background of a better result in the Y-POST-LAT_L test, and a higher result in the test of flexor muscle resistance to fatigue (lower values of CRF correspond to higher resistance to fatigue) lies behind poorer results in the Y-POST-LAT_L test.

The other factors are independent from the YBT results. Coefficient of correlation of variables representing the YBT results with these factors does not exceed $r = 0.31$.

Factor 3 explains 14% of communality and is loaded on by variables of relative torques of knee flexors (*τr* Flex_L, *τr* Flex_R), the ratio of relative torques of extensors to flexors of the left extremity (*τr* Ext_L/Flex_L) and ranges of motion in joints of the left and right extremities (ROM_HKA_L, ROM_H_L, ROM_K Flex_R). Factor loading values of these variables range from $r = 0.50$ to $r = 0.75$. It should be noted that subjects with higher values of relative torques of flexors and poorer ratios of knee joint extensor to flexor force achieved smaller ranges of joint mobility.

Factor 4, explaining 11% of communality is loaded on by the variables characterising total range of motion in the left hip joint (ROM_H_L) and relative torques of knee joint extensors of the left and right extremities (*τr* EXT_L, *τr* EXT_R).

The last, 5th factor, explaining 7% of communality is loaded on by the variables characterising total range of motion in the ankle joints. A noticeable relationship with these variables was found only for the FBT_L result ($r = 0.48$).

Table 3. Factor structure of the results of the right lower extremity YBT determined with PCA (varimax rotation)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
FBT_R	0.07	–0.42	0.12	0.34	–0.19
Y-ANT_R	0.43	–0.41	0.31	0.47	0.25
Y-POST-MED_R	0.70	–0.35	0.31	0.24	0.26
Y-POST-LAT_R	0.59	–0.37	0.22	0.05	0.29
Y-CS_R	0.69	–0.44	0.32	0.25	0.32
ROM_HKA_R	0.75	0.3	–0.44	0.22	–0.09
ROM_H_R	0.69	0.1	–0.38	–0.01	–0.01
ROM_K Flex_R	0.55	0.13	–0.54	0.05	0.04
ROM_A_R	0.29	0.50	–0.06	0.56	–0.25
ROM_HKA_L	0.72	0.13	–0.50	–0.28	–0.11
ROM_H_L	0.49	–0.08	–0.40	–0.67	0.08
ROM_K Flex_L	0.55	0.26	–0.45	0.21	0.02
ROM_A_L	0.39	0.27	–0.12	0.45	–0.40
CRF Ext_R	0.14	0.4	–0.03	–0.08	0.61
τr EXT_R	0.63	0.06	0.51	–0.36	–0.16
CRF Flex_R	–0.06	0.77	–0.03	0.01	0.27
τr Flex_R	0.42	0.56	0.49	–0.24	–0.16
τr Ext_R/Flex_R	0.19	–0.62	–0.05	–0.12	–0.02
CRF Ext_L	–0.11	0.22	–0.15	0.07	0.64
τr EXT_L	0.61	0.02	0.54	–0.37	–0.16
CRF Flex_L	–0.08	0.65	0.21	–0.06	0.3
τr Flex_L	0.39	0.49	0.73	–0.11	–0.14
τr Ext_L/Flex_L	0.21	–0.57	–0.39	–0.33	0
Share of variance	0.24	0.17	0.14	0.11	0.08

FBT – "Flamingo balance test"; Y-ANT – Y-anterior; Y-POST-MED – Y-posteromedial; Y-POST-LAT – Y-posterolateral; Y-CS – Y-composite score; ROM – range of motion; Flex – flexion; Ext – extension; CRF – the coefficient of regression of force; τr = relative muscle torque; H – hip; K – knee; A – ankle; L – left; – = right.

The factor structure of the YBT results for the right lower extremity is similar to this obtained for the left one. The structure of the five factors explains 74% of communality in total. Factor 1, explaining 24% of variance of the variables, is loaded on by the variables characterising the YBT results and all measured ranges of motion in hip and knee joints. Only total mobility of the ankle joints is not loaded onto this factor. The YBT results were strongly correlated with relative torques of knee joint extensors of both lower extremities (τr EXT_L, $r = 0.61$, τr EXT_R, $r = 0.63$).

Factor 2, explaining 17% of communality of the variables includes markedly lower values of factor loadings with respect to the YBT results. Factor loading values captured by this factor range from $r = 0.50$ to $r = 0.77$. This factor is loaded on most strongly by the variables that describe the results of the test of resistance to fatigue of flexors of knee joints, the ratio of relative torques of extensors to flexors and relative torques of flexors of knee joints of both lower extremities. Additionally, the factor structure includes also the total range of motion in the ankle joint of the right extremity (ROM_A_R, $r = 0.50$). Its higher values were positively correlated with the level of relative torques and force regression coefficient, and negatively correlated with the extensor to flexor ratio of relative muscle torques.

Factor 3 explains 14% of communality and is loaded on by the variables of relative torques of knee flexors and extensors (τr Flex_L, τr Flex_R, τr EXT_R, τr EXT_L), and shows differences movement in joints between the left and right extremities (ROM_K Flex_R ROM_HKA_L). Factor loading values of these variables range from $r = 0.49$ to $r = 0.73$. In subjects achieving higher values of relative torques of extensors and flexors, at the same time lower values of joint mobility were observed. It should be recalled that variables describing the ratios of extensor strength to flexor strength in the knee joints were loaded onto factor 2.

The structure of factor 4 differs from the corresponding factor for the left extremity but is similar to factor 5 calculated for that extremity. The variables characterising the level of achieved relative torques of knee joint extensors were previously loaded onto factor 1 and for this reason they are not included in factor 4. It explains 11% of communality and is loaded by the variables characterising the total range of motion in the ankle joints of the right and left lower extremities (ROM_A _R and ROM_A_L) along with the result of the right extremity balance test (FBT_R).

The last, 5th factor, explains 8% of communality. It is loaded by the variables characterising the values of force of regression coefficients of knee joint extensors of both extremities (CRF Ext_R, CRF Ext_L). These variables showed high autonomy with respect to other factors, achieving low values of factor loadings in them. In the structure of YBT results for the left extremity these variables were not loaded onto any of the identified factors.

4. Discussion

The Y-Balance Test is a modification of the standardised Star Excursion Balance Test (SEBT) [20].

Based on the amount of different types of movement analyzed in this test, dynamic postural stability may be assessed as a resultant of the joint range of motion, muscle elasticity and strength, and neuromuscular control [21]. The obtained result is directly proportional to postural stability, what means that higher YBT results are associated with better postural stability [22].

Evaluation of the effect of motor tasks (running and jumping) on static stability in basketball players in the tests on the force platform was presented by Struzik et al. [23]. However, the studies conducted by Hrysomallis et al. show that there is a need for parallel testing of dynamic stability whenever it has a critical effect on the effectiveness of the technique used. They have proved that assessment of postural stability in a static test, on a stabilometric platform among others, does not give results similar to those obtained during dynamic trials [24].

An evaluation of the injury risk with the use of the dynamic tests assessing postural stability is a frequent subject matter of research. In a study on female basketball players, Plisky et al. have shown that weakened postural stability showed by the SEBT is a reliable measure of the risk of injury occurrence in the future [3]. The subjects who achieved lower results in this test had a 6.5-fold higher lower extremity injury risk. Herington's studies have shown that a low YBT result enables identification of people with chronic ankle instability (CAI) as well as those who have experienced an injury of the anterior cruciate ligament [25]. Using the YBT in a group of university athletes Smith et al. have shown that a difference between both lower extremities in the anterior reach result higher than 4 cm may be indicative of an increased risk of a non-contact injury of the lower extremity [26]. Similar conclusions were drawn by Plisky et al. who have found that subjects with anterior reach the YBT asymmetry higher than 4 cm (understood as the difference between the results obtained for the left and right lower extremities) have a 2.5-fold higher risk of a lower extremity injury [3].

In relation to the issues addressed in this piece of work, interesting seem the reports of Lee et al. who were looking for relationships between the YBT and lower extremity muscle strength in adults [27]. Their study shown a positive correlation between the strength of the hip extensors and knee flexors and anterior reach YBT result, and a positive correlation between the strength of the hip extensors, hip abductors and knee flexors and posteromedial reach result. They also noted a positive correlation between the strength of the hip extensors and knee flexors and the YBT posterolateral reach. The strength of the lower extremities was found to influence the YBT efficiency. Therefore Lee et al. suggest that appropriate training programmes for older people should be used that would involve not only strengthening exercises but also the YBT to improve dynamic balance [15].

The factor structure found in this study appeared to be clear and substantively interpretable. When comparing factor structures obtained for both lower extremities it should be stressed that extracted 5-factor structures satisfactorily explained communality (76% and 75%). In both cases the structures of the first three factors appeared much similar to each other. From the point of view of the objectives of this work, the structure of factor 1 appeared to be the most important. It points to a strong and unquestionable effect of ranges of motion of the knee and hip joints of both lower extremities and of the relative knee extensor strength performance on the YBT results. As all variables with high loading captured by factor 1 have the same positive sign of the coefficient of correlation of the variable with the factor, better test results are achieved by subjects with higher values of relative torques of knee extensors and with higher mobility of lower extremity joints. The first of the factors isolated in the analysis points to a hybrid structure of the YBT. The result of this test (irrespective of movement direction) is substantially affected both by total joint ranges of motion and relative strength performance of knee joint extensors of the subjects. Based on the above, it may be stated that these are the two components that are measured by this test.

A part of the variables appeared to be autonomous with respect to the YBT results and did not load onto the same factor that was loaded on by the results of the analysed test. These autonomous variables include total ranges of motion for ankle joints, strength regression parameter values, relative values of torques of knee joint flexors or knee joint extensor to flexor torque ratios. Obtained factor structure confirms previous observations on correlative relationship of the YBT results with the strength of knee joint extensors that play a key role in maintenance of stable posture during test performance [25].

It should be stressed that the structure found in our study points to autonomy of the results of the assessment of strength performance of knee joint flexors with respect to the YBT results. These variables were loaded onto factor 2 for the right lower extremity and factors 2 and 3 for the left lower extremity, respectively. Obtained results are in opposition to the previous ones [25]. Performance of the Y-Balance Test generates the phenomenon of co-contraction of knee joint antagonist muscles, particularly when approaching the maximum reach. Therefore the active work of knee joint flexors may hamper achievement of better YBT results. Thus declaration of a positive correlation of the YBT results with the strength of knee joint flexors seems not justified. In the YBT, engagement of antigravitational muscles (extensors) is much higher, as compared to flexors. This explains placement of relative muscle torques of knee joint extensors in the same factor as the YBT results.

The isolation of the factor loaded on by ankle joint ranges of motion, autonomous with respect to the YBT results, seems also an interesting observation. One should suspect that the larger ranges of motion in all lower extremity joints, the higher test result will be achieved. This result was confirmed for total ranges of motion in hip and knee joints and in total range of motion of all three joints. This manifested as consistent loading of these variables onto factor 1 in both lower extremities. The level of mobility of the ankle joints did not play any important role in achievement of a high YBT result, probably due to a minor input of this joint into the total range of motion of all joints. The ankle joint movement range variable fell within the same factor as the FBT result. This points to a significant effect of this variable on FBT result, which is confirmed by its movement structure. Extracted factor structure for both extremities allows for a declaration that the YBT and the FBT are autonomous with respect to each other. The first test measures a combination of joint mobility with strength performance of extensors and the result of the second one depends, among others, on large range of plantar and dorsal foot flexion.

In the assessment of the YBT accuracy, measurement of muscle strength in anaerobic conditions was also used that was represented by the CRF variable. Contribution of muscle strength component appeared not to have any significant effect on the YBT result, however it was related to the level of relative strength performance and extensor to flexor strength ratio (factor 2).

Although examination of the YBT accuracy shows its hybrid nature, both similarity of factor 1 for both extremities and a clear structure of this factor (this factor was loaded on by the same variables) allow to declare that this test is a good predictor of lower extremity joint mobility and strength performance of extensors. It should be underlined at this point that simultaneous control of these two elements by the nervous system fits well into the concept of postural stability.

The extracted factor structure may bring measurable benefits to future investigators enabling a limitation of the number of the measured variables. It will be sufficient to select representative variables with the highest factor loadings to obtain a similar relationship between the YBT results and the structure of motility of the subjects.

An indubitable value of our observations is also the knowledge of these motility aspects that are not measured by the YBT. They include all these variables showing autonomy that are captured by other factors and are not present in factor 1.

Although the selection of the subjects was intentional, the authors of this work are aware of its limitations. They are shown in the conclusion drawn with respect to one sex and to a defined age of the subjects. Therefore it seems necessary to perform similar studies in the future in groups of subjects of a different age and for both sexes.

5. Conclusions

The extracted factor structure points to a hybrid structure of the YBT and shows its accuracy in measurements of lower limb joint mobility and strength performance of knee joint extensors.

The strength performance and resistance to fatigue of joint flexors, ankle joint ranges of motion and FBT results appeared autonomous with respect to the YBT results.

The similar structure of main factors in both lower extremities enables a reduction in the number of variables describing variance of the YBT results.

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