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A NEW APPROACH TO ACTIVE FLEXIBILITY MEASUREMENT IN STUDENTS OF SPORTS SCIENCES FACULTIES

NOV PRISTOP K MERJENJU AKTIVNE GIBLJIVOSTI PRI ŠTUDENTIH FAKULTET ZA ŠPORTNE VEDE

ABSTRACT

The aim of the study is the determination of the hamstrings, hip muscles, and lower and upper muscles' active flexibility. Thus, by using a new method of the measurement of active flexibility which is based on angle degree, we aim to provide information about the contribution ratio of hamstrings, hips, and lower and upper back muscles on reachability performance. A total of 26 physical education and sports science faculty girls (weight: 57.7kg, height: 164.2cm), and 128 boys (weight: 72.1kg, height: 176.9cm) was included. To measure the flexibility of the students the Kinovea-0.9.4-x64.exe program was used. Measurements included tests such as the LUBAD, LBLBAD, LBPAG, SRT and MSRT. In the data analysis one-way ANOVA, Pearson correlation, and the percentage formula: "%= (X / X) *100" was used. Correlations between reachability tests such as SRT and MSRT, and tests which are supposed to measure the lower and upper back effect of reachability LUBAD, LBLBAD are statistically significant ($p<0.05$). In girls, just 23%, and boys 26% of active flexibility is caused by hamstrings and hip muscles, while in the girls 77%, and in boys, 74% of the active flexibility was caused by the lower and upper back muscles. The girls resulted to use a higher ratio the upper back flexibility to cover the lack of hips, and hamstrings muscles flexibility while they perform reachability tests. Thus, the reachability is not caused just by hamstrings, and hips muscles, but also it is affected by the lower and upper back muscles' active flexibility.

Keywords: Sit-and-reach, Baseline (Modified) Sit-and-reach, Validity, Lower Back, Upper Back, Hamstrings

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IZVLEČEK

Cilj študije je določitev aktivne gibljivosti posameznih mišic (stegenskih, kolčnih in mišic spodnjega in zgornjega dela hrbta) in razmerja med njimi s pomočjo kotnih stopinj. V raziskavo je bilo vključenih 26 deklet s Fakultete za telesno vzgojo in šport (telesna teža: 57.7 kg, telesna višina: 164.2 cm) in 128 fantov (telesna teža: 72.1 kg, telesna višina: 176.9 cm). Za merjenje gibljivosti študentov je bil uporabljen program Kinovea-0.9.4-x64.exe. Meritve so vključevale teste, kot so LUBAD, LBLBAD, LBPAG, SRT in MSRT. Pri analizi podatkov so bili uporabljeni enosmerna ANOVA, Pearsonov koeficient korelacije in odstotna formula (uporabljena je bila formula "% = (X / X) *100). Korelacije med testi gibljivosti, kot sta SRT in MSRT, ter testi, ki naj bi merili gibljivost spodnjega in zgornjega dela hrbta LUBAD, LBLBAD, so statistično značilne ($p<0.05$). Pri dekletih prispevajo stegenske in kolčne mišice le 23% k aktivni gibljivosti pri zgoraj omenjenih testih, medtem ko pri fantih ta odstotek znaša 26%. Večji delež aktivne gibljivosti tako pri obeh spolih prispevajo mišice spodnjega in zgornjega dela hrbta (dekleta 77%, fantje 74%). Dekleta so slabšo gibljivost spodnjih okončin (stegenskih in kolčnih mišic) pri testih kompenzirala z boljšo gibljivostjo mišic zgornjega dela hrbta. To dokazuje, da so za aktivno gibljivost v večji meri odgovorne mišice zgornjega in spodnjega dela hrbta, in ne samo stegenske in kolčne mišice.

Ključne besede: predklon sede, predklon sede prilagojen, veljavnost, spodnji del hrbta, zgornji del hrbta, stegenske mišice

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INTRODUCTION

As the ability to assume and maintain extended positions using only the tension of the agonists and synergists while the antagonists are being stretched (Sabhachandani & Rani, 2011), active flexibility is a key factor in performance parameters in many sports branches such as gymnastics branches, dance, etc. High active flexibility and a good compromise between strength and flexibility are advisable for high-quality performance (Donti, Tsolakis, & Bogdanis, 2014; Purcell & Micheli, 2009). By providing higher active flexibility (mobility) actively moving through a range of motions known as with high correlation to competition performance may be significantly increased (Berisha, 2021a; Schwab, Diangelo, & Foley, 2006). As the flexibility decreases with age and high speed of development, in both cases, girls perform better than boys (Catley & Tomkinson, 2013; Coknaz, 2017; De Miguel-Etayo et al., 2014; Yalnız, 2016). Many countries such as all European countries, Kosovo, Australia, Turkey, Serbia, etc., (Catley & Tomkinson, 2013; Örjan, Kristjan, & Björn, 2005; Ortega et al., 2011; Wilczewski, Sklad, Krawczyk, Saczuk, & Majle, 1996) pose norm values and level of flexibility which in most situations is based on the values carried about by applying sit-and-reach test (SRT) (Castro-Pinero et al., 2010; Hui & Yuen, 2000). But, the accuracy of all previous results which still are in use depends on the validity of tests used to measure the flexibility.

Interestingly, although many types of research about sit-and-reach tests, there is little research evidence that any kind of sit-and-reach test adequately measures low-back, upper-back, or hamstrings flexibility. There is controversy in the literature as to whether sit-and-reach tests assess low-back flexibility and/or hip flexibility. Based on the fact that validity is the degree to which a test or test item measures what it is supposed to measure (Baumgartner, 2007; Morrow, 2011), sit-and-reach test measures reachability which is affected by anthropometric features and does not mean directly that it is valid to test for low-back, upper-back or hamstrings active flexibility. Reasons for this are anthropometric factors. Longer or shorter legs, longer or shorter arms, and a longer or shorter trunk may be reasons for better or worse reach performance (Remian & Manske, 2009). To avoid the affection of the anthropometric features on the sit-and-reach test results, it was developed a “modified sit-and-reach” method of measurement. The back-saver sit-and-reach test has been proposed as a healthier alternative to the classical sit-and-reach test (Plowman & Meredith, 2013). Unfortunately, as the classic method fail to measure and is affected by the long arms, similarly baseline (Modified Sit and Reach Test MSRT) method may be affected by the short arms. So, to measure the hips, lower body, upper

body, and hamstrings muscle flexibility, we should develop a method that measures that flexibility and is not affected by the anthropometric features.

Based on the need to develop a new method of active flexibility measurement, the aim of the study is the determination of the hamstrings, hip muscles, and lower and upper back muscles' active flexibility. Thus, by using a new method of the measurement of active flexibility which is based on angle degree, we aim to provide information about the contribution ratio of hamstrings, hips, and lower and upper back muscles on reachability performance.

METHODS

To carry out aimed conclusions which is the determination of the hamstrings, hip muscles, and lower and upper muscles' active flexibility level by using the angle degree method, the causal relational research model was used.

Participants

In this study, 26 physical education and sports science faculty girls whose average body weight was 57.7±6.15kg, and body height average of 164.2±4.38 cm, and 128 boys whose average body weight was 72.1±10.53 kg, and body height average of 176.9±5.20 cm were included. Athletes were informed about the activities and tests, which were made for the study. Besides this, students signed an informed consent after being informed about the benefits and risks (even though there was no predicted risk) of the applied activities and tests. The study procedures were approved by the local ethics committee at Istanbul Gelisim University in 18.08.2022 (meeting number: 2022-13), approval decision number 2022-13-37, and they were conducted according to the Helsinki declaration (2013).

Tests included in the study

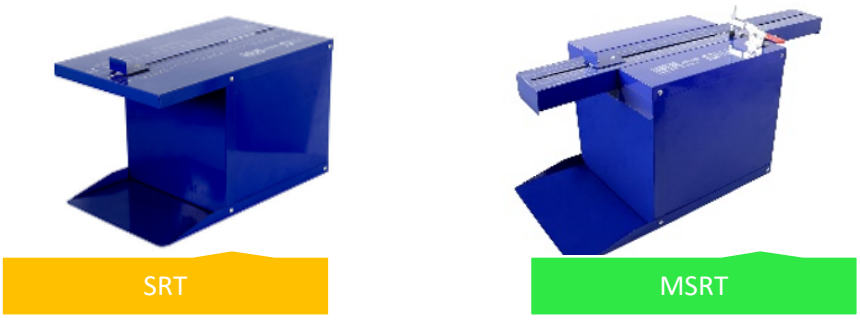
In order to measure the sit and reach performance SRT and MSRT tests were applied as they have been explained below. In the new approach to the assessments the LUBAD, LBLBAD, and LBPAG test protocols have been applied as they are explained below. Each participant has been photographed from the lateral side. Participants are dressed in thin t-shirts and short shorts that provide visibility to the body joints. The anatomical (see each test protocol below) zones used as the center angle degree s been marked. Besides using the seat-and-reach box, measurements were made by using the Kinovea-0.9.4-x64.exe program (Berisha, 2021b; Kinovea-0.9.4-x64.exe., 2021). The tests were made by all authors of the study. However, the

flexibility test protocols, anatomic zones for angle degrees, and analyses of them have been made by the first author of the study, who is a Ph.D. of sports science, an artistic gymnastics coach, and experienced in 2D biomechanics analysis.

Sit-and-reach Test (SRT): Several sit-and-reach tests are commonly used in health-related and physical-fitness test batteries to evaluate the hamstring and lower back flexibility (Hui & Yuen, 2000). The tests in which a fingertips-to-tangent feet distance is measured are probably the most widely used linear measures of flexibility (Figure 1a) (Castro-Pinero et al., 2010).

Modified Sit-and-reach Test (MSRT): The active flexibility was measured by using the modified sit-and-reach test. The test application was made by following the instructions of the seat reach test (Council of Europe 1983, Council of Europe 1987).

Figure 1. Sit and reach tests used in the study.



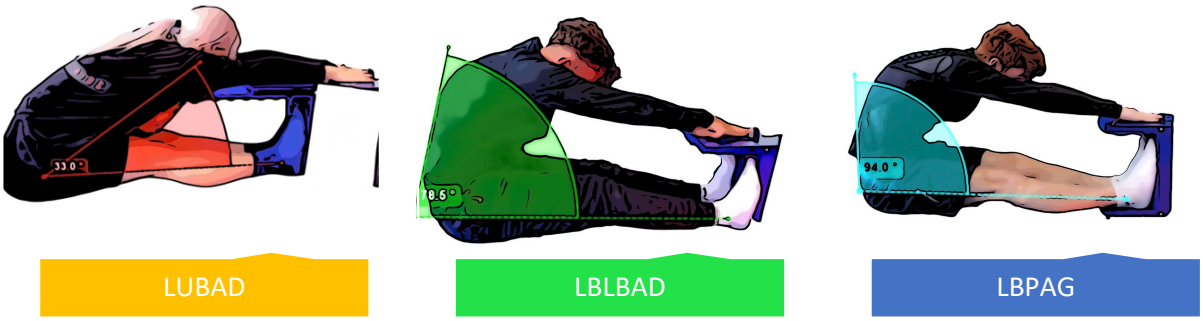
a) SRT (Sit-and-reach Test); b) MSRT (Modified Sit-and-Reach Test)

Lower-Upper Body Angle degree (LUBAD): The test measures the active flexibility of the hamstrings, hips, lower back, and upper back muscles. Thus, the test is designed to measure the reachability of the testers. Besides measuring the reach distance in cm, during the test lower-upper body angle degree was measured (as the center of angle was determined greater trochanter, first-line were from greater trochanter to acromion and second line from the greater trochanter to the lateral epicondyle of the femur) (see Figure 2a) (Süzen L.B., 2017).

Lower Body-Lower Back Angle Degree (LBLBAD): The test measures the active flexibility of the hamstrings, hips, and lower back muscles. Thus, the test is designed to leave out the upper back muscles' active flexibility during the reachability of the testers. The first line of angle starts from the lumbar spine, (L5) across the lumbar spine (L1) to the thoracic spine, and the second line starts from the lateral epicondyle of the femur which across the greater trochanter and meets the other line of the angle which come from the lumbar spine (see Figure 2b) (Süzen L.B., 2017)

Lower Body-Pelvic Angle Degree (LBPAG): The test measures the active flexibility of the hamstrings, and hips muscles. Thus, the test is designed to leave out the lower and upper back muscles' active flexibility during the reachability of the testers. The first line of angle starts from the end of the line and comes across the lateral epicondyle to the greater trochanter. Thus, pelvic torsion is measured which is expressed in angle degree (see Figure 2c) (Süzen L.B., 2017).

Figure 2. New approach of sit and reach measurement and back inclusion ratio on the reachability.



a) LUBAD (Lower-Upper Body Angle Degree); b) LBLBAD (Lower Body-Lower Back Angle Degree); c) LBPAG (Lower Body-Pelvic Angle Degree).

Data analysis

The data analysis has been made by using SPSS 26 packet program. The distribution (normality) of the data has been tested by using the skewness (> 1 - positive, 0 - normal, < - 1 - negative) and kurtosis (> +2 leptokurtic, 2 mesokurtic, < -2 platykurtic) values. Correlations between reachability tests and back angle degrees were tested by using Pearson correlation analysis. The significant correlation coefficient is $p<0.05$. The difference between angle degrees on the back (LUBAD, LBLBAD, and LBPAG) has been determined by using a one-way ANOVA (Post-Hoc Tukey) analysis. And, the rate of effect of back angles (LUBAD, LBLBAD, LBPAG) on the reachability (SRT, MSRT) "%= (X / X) *100" formula was used. To determine the inclusion ratio (%) of the lower and upper back muscles and hamstring, hips, and pelvic muscles LUBAD angle and LBPAG angle degrees were divided in the middle by the LBLBAD. To measure the flexibility of the students the Kinovea-0.9.4-x64.exe program was used.

RESULTS

Table 1. The descriptive statistics normality of the active flexibility and angle degree tests.

	Variables	Range	Min	Max	X̄±SD	Skew	Kurt
Girls (♀)	SRT	32.8	15.7	48.5	33.9±9.57	-.543	-.624
	MSRT	36.8	24.5	61.3	43.4±10.21	-.361	-.907
	LUBAD	43.2	32.5	75.7	48.9±11.15	1.013	.625
	LBLBAD	46.8	40.0	86.8	55.8±12.73	1.047	.616
	LBPAG	44.3	66.0	110.3	84.6±10.76	.265	-.087
Boys (♂)	SRT	40.7	10.3	51.0	29.7±8.11	-.058	-.104
	MSRT	45.4	19.6	65.0	42.5±8.57	.141	.030
	LUBAD	42.6	35.4	78.0	54.4±9.41	.314	-.131
	LBLBAD	55.6	34.3	89.9	64.4±12.53	.051	-.641
	LBPAG	33.50	74.10	107.60	90.9±6.96	.034	-.372

Sit and Reach (SRT), Modified Sit-and-reach Test (MSRT), Lower-Upper Body Angle Degree (LUBAD), Lower Body-Lower Back Angle Degree (LBLBAD), Lower Body-Pelvic Angle Degree (LBPAG).

Based on the angle degrees descriptive values given in Table 1, it can be seen that the distribution of the data results seems to be normal (mesokurtic), and not significantly skewed positively or negatively. The angle degrees that occurred in the back are different from a gender perspective (based on average values). While the differences between boys and girls in LUBAD are smaller in favor of girls, the differences in LBLBAD and LBPAG seem to be more important in favor of girls.

When results are analyzed from another perspective, the LUBAD angle degree is different from the angle degrees that occurred on other parts of the back such as LBLBAD and LBPAG, which is proof of the effects of back elasticity on the reachability measured by SRT and BLSRT test.

Table 2. Difference between angle degrees occurred in back while sit and reach test (Back curve effect on the sit reach ability).

Gender	Variables	X̄±SD	F	P	Tukey
Girls (♀)	[1] Lower-Upper Body Angle Degree	48.9±11.15	69.383	.000	1<3
	[2] Lower Body-Lower Back Angle Degree	55.8±12.73			2<3
	[3] Lower Body-Pelvic Angle Degree	84.6±10.76			
Boys (♂)	[1] Lower-Upper Body Angle Degree	54.4±9.41	463.68	.000	1<2
	[2] Lower Body-Lower Back Angle Degree	64.4±12.53			1<3
	[3] Lower Body-Pelvic Angle Degree	90.9±6.96			2>3

$p<0.05$, LUBAD: Lower-Upper Body Angle Degree, LBLBAD: Lower Body-Lower Back Angle Degree, LBPAG: Lower Body-Pelvic Angle Degree.

In Table 1, it can be seen that there are statistically significant differences between the LUBAD, LBLBAD, and LBPAG tests on the reachability during the execution of the sit-and-reach test and baseline sit-and-reach test in both genders ($p<0.05$). Expecting the differences between LUBAD and LBLBAD in girls, resulted to be not significantly different ($p>0.05$).

Table 3. Correlations between sit and reach (classic method) and baseline sit and reach.

Gender	Flexibility tests	Correlations	LUBAD	LBLBAD	LBPAG
Girls (♀)	Sit and Reach (cm) (SRT)	r	-.875**	-.793**	-.486*
		p	.000	.000	.012
	Baseline Sit and Reach (cm) (MSRT)	r	-.779**	-.715**	-.278
		p	.000	.000	.169
Boys (♂)	Sit and Reach (cm) (SRT)	r	-.829**	-.466**	-.765**
		p	.000	.000	.000
	Baseline Sit and Reach (cm) (MSRT)	r	-.666**	-.340**	-.604**
		p	.000	.000	.000

$p<0.05$, LUBAD: Lower-Upper Body Angle Degree, LBLBAD: Lower Body-Lower Back Angle Degree, LBPAG: Lower Body-Pelvic Angle Degree.

In Table 2 it can be seen that the girl's reachability in SRT and MSRT increases in parallel with the decreases of the LUBAD (SRT: r=-.875, MSRT: r=-.779), but not at the same ratio of correlations of LBLBAD (SRT: r=-793, MSRT: r=-.715) and LBPAG (SRT: r=-.486) resulted to be significant to the SRT and MSRT test, where the correlation ratio is meaningfully lower compared to the LUBAD correlation ratios. In addition, correlations between MSRT and LBPAG resulted to be significantly not different (r=-.278).

Similar results can be seen in boys, where the reachability in SRT (LUBAD: r=-.829, LBLBAD: r=-.466, LBPAG: -.765), and MSRT (LUBAD: r=-.666, LBLBAD: r=-.340, LBPAG: -.604) resulted to be statistically significant but the ratio of the correlation is meaningfully lower in LBLBAD and LBPAG compared to the correlation ratio of the LUBAD.

Figure 3. Girls' (A) and boys' (B) reachability percentage.

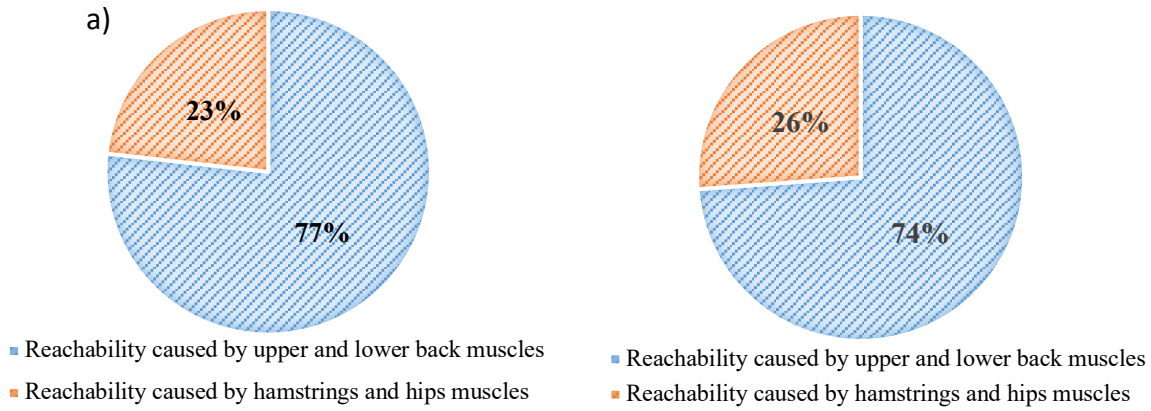


Figure 4a has shown that while the 77% of the reachability of the girl students is caused by the upper and lower back muscles, 23% of it is caused by the hamstrings and hips muscles' active flexibility. Similar to the girls, Figure 4b has shown that 74% of the reachability of the boy students is caused by the upper and lower back muscles, and 26% of it is caused by the hamstrings and hips muscles' active flexibility.

DISCUSSION

The study was made to develop a new method of active flexibility measurement which is being measured by using the methods or tests which's accuracy and ability to explain the results are low. The most common test in use for active flexibility is sit-and-reach which is earnestly affected by the anthropometric features and the ability to explain the ratio of muscle groups' inclusion is low. To address the problem, there is a method called the baseline method which is developed to remove the mentioned problem in the sit-and-reach test. Unfortunately, as the sit-and-reach method tends to show more flexible people whose arms, and the trunk is long or whose legs are short, similarly baseline sits and reach test tends to show more flexible people whose arms are short. There are studies in the literature where the measurement of flexibility was made by using different methods to increase the accuracy of measurement. In the study made by (López-Miñarro, Sáinz de Baranda, Rodríguez-García, & Yuste, 2008), there was used an inclinometer in order to measure the flexibility (López-Miñarro et al., 2008; Youdas, Krause, & Hollman, 2008).

So, let us discuss the new approach to measurements provided by this study. As can be seen in Tables 1 and 2, in both genders lower-upper body angle degrees were smaller than lower body-

lower back and lower body-pelvic angle degrees, which means that reachability in sit-and-reach and baseline sit-and-reach tests is not caused just by the hip's muscles flexibility. A significant amount of reachability is caused by upper back muscles' flexibility. This contradicts the sit-and-reach test and baseline sit-and-reach methods for testing reachability of only hamstrings and hips muscles.

Three measurement methods have shown that girls' active flexibility is higher than boys. In addition, the largest differences occur in lower body-lower back angle degrees, where girls' results are much better than boys. The pelvic tilt explained more than 60% of the variance (distance reached in the SR test) and lumbar flexion explained more than 80% of the variance (Muyor, Zemkova, Stefanikova, & Kotyra, 2014). In addition, findings of the study shown that while in the boys' differences between lower-upper body angle degree and lower body-lower back angle degree resulted to be significant, the same comparisons did not significantly differ among girls. In other words, in comparison to the girls, boys have to use more flexibility of the upper back and erector muscles to cover the lack of active flexibility of the lower back, hips, and hamstrings muscles. Among individuals with short hamstrings, increased flexion of the thoracic spine and decreased range of motion of the hip and lumbar spines were observed during a toe touch test (Gajdosik, Albert, & Mitman, 1994).

Furthermore, while 77% of the reachability of the girl students is caused by the lower and upper back muscles, 23% of it is caused by the hamstrings, and hips muscles' active flexibility. Similar to the girls, Figure 2 has shown that 74% of the reachability of the boy students is caused by the upper back, and 26% of it is caused by the hamstrings, and hip muscles active flexibility.

The analysis of different perspectives given in Table 2 has shown that besides expected significant correlations between lower-upper body and reachability tests such as sit-and-reach and baseline sit-and-reach, although a small amount of correlation between reachability tests and lower body-lower back and lower body-pelvis angle degrees resulted to be significant in both genders. These results are proof of the fact that reachability does not depend just on the flexibility of the lower back, hips, and hamstrings muscles. As was mentioned in the previous parts of the discussion which highlighted boys, both genders use the upper back and erector muscles' active flexibility to increase reachability measured by using the sit-and-reach and baseline sit-and-reach test. A similar result has been found in the literature reporting that a moderate correlation was found between the hip joint angle and the sit-and-reach test ($r=0.48$) (Kawano et al., 2010).

These results verify the validity of the main hypothesis of this study which claims that reachability is not caused just by the hamstrings and hips muscles as the sit and rich method is based on. Several sit-and-reach tests are commonly used in health-related and physical-fitness test batteries to evaluate the hamstring and lower back flexibility (Hui & Yuen, 2000). The tests in which a fingertips-to-tangent feet distance is measured are probably the most widely used linear measures of flexibility (Castro-Pinero et al., 2010). However, there is little research evidence that any kind of sit-and-reach test adequately measures low-back flexibility.

Based on the results of the study, reachability performance measured by the sit-and-reach and baseline sit-and-reach test is not limited to the lower back, hips, and hamstring muscles. Upper back muscles are directly involved in the reachability performance where the girls resulted to use in a higher ratio (77%) the upper back flexibility, in order to cover the lack of hips, and hamstrings muscles flexibility while they perform tests such as sit-and-reach and baseline sit-and-reach.

The method used in this study may be more beneficial to determine the level of active flexibility separately in the upper back, lower back, hips, and hamstrings muscles. In addition, in case the flexibility of these muscle groups is measured by using sit-and-reach test anthropometric features will interfere the results. The accuracy of muscles flexibility determination will be lower because among the factors that affect the reachability are not just muscles flexibility but also anthropometric features such as long arms and trunk. At the same time, long legs may cause a decrease in reachability which is expressed in centimeters (Remian & Manske, 2009).

CONCLUSION

Finally, it can be concluded that a measurement method of reachability and active flexibility of muscles such as the upper back, lower back, hips, and hamstrings, which is based on three (LUBAD, LBLBAD, LBPAD) angle degrees, is more valid and reliable method and provides more information compared to the previous methods such as sit-and-reach and baseline sit-and-reach tests which give results in centimeters and cannot separate the ratio of inclusion of the muscles and anthropometric features in reachability performance.

However, both sit-and-reach and baseline (modified) sit-and-reach tests are valid tests for measurement of the reachability on the bench without any explanation about which muscles are

the cause of the reachability, anthropometric features inclusion ratio, or without being able to explain which group of muscles have a lack of high active flexibility.

In the case of a needed reachability score, but no need for an explanation of the reachability and included factors, sit-and-reach and baseline (modified) sit-and-reach tests are valid to be used.

In the case of needed reachability score and necessarily needed explanation of the reachability and included factors such arm, trunk, and leg length or upper back, lower back, hips or hamstrings muscles inclusion ratio, a method is given in this study which is based on angle degrees (LUBAD, LBLBAD, LBPAD) is more valid and may give a result with more accuracy and details.

To increase the accuracy of our measurement method for active flexibility, where results are given in angle degrees, not in centimeters, carrying out the results using the x-ray method instead of using photographs of the sit-and-reach position would be more appropriate from an accuracy perspective. Another method of measurement for active flexibility which may be appropriate is the inclinometer.

Strengths and Limitations

The strength of the study is based on the fact that the new approach of active flexibility measurement provided by this study seems to be a more valid and reliable method and provides more information compared to the previous methods such as sit-and-reach and baseline sit-and-reach tests which give results in centimeters and cannot separate the ratio of inclusion of the muscles and anthropometric features in reachability performance.

The study is limited to physical education and sport science students. The developed new approach of active flexibility measurements may not be valid for the different categories of the population. The anatomical points of the angles were made on sportive light wear. Determining the anatomical points directly on the skin in future studies will reduce the measurement error.

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Declarations of Conflicting Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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