Infrared Sensor Technology (IST) Test as a Tool for Assessment of Flexibility

Syahruddin Syahruddin[1,A,F], Imam Safei Imam[2,B-C], Lungit Lungit[2,E], Ramdan Pelana Ramdan[3,E], Bagus Winata Bagus[3,D]

[1]Universitas Negeri Makassar
[2]Universitas Negeri Lampung
[3]Universitas Negeri Jakarta

Received: 2019-05-18
Accepted: 2019-06-16

Abstract:
Introduction: The eEvaluation of flexibility is important to for coaches to assess their players' flexibility status, predict future performance in exercise or competitions, assess injury risk and even detect talented players. The aim of this research was to develop a new flexibility test to examine the forward split in athletes.
Material and methods: In this study, 15 gymnasts, 10 Taekwondo athletes, 5 football players, and 10 karate athletes 40 athletes (20 males and 20 females) who volunteered for thise experiment and were evaluated in terms of the type of exercise they had mostly performeda common movement pattern, the forward split: 15 gymnasts, 10 Taekwondo athletes, 5 football players, and 10 karate athletes. In the experimental condition, participants performed the forward split on a mattress using infrared sensor technology (IST test), and, afterward, they performed the forward split on a mattress without infrared sensor technology (N-IST test). Two trials of this procedure were conductedfor Trial I.
Results: For concurrent validity, no significant difference in the average distances of the anterior superior iliac spine (ASIS) from the mattress in Trials I and II was found between the IST and N-IST tests — $p = 0.664$ and $p = 0.710$, respectively.
Conclusions: The findings of this study confirm the concurrent and construct validity of the IST test, which was created to measure the height of the ASIS from the mattress in a forward-split test. Thus, this test can be used by coaches, athletes, and sports scientists to improve and monitor the forward-split tests of athletes in training programs.

Keywords: muscle, athletes, sit and reach, parallax error, sports technology.

Email: fransiskusasisibaguswinata@gmail.com

Introduction

Exercise and training is ~~the most~~an important component used to ~~powerful way of improving the~~help an ~~quality of~~ athlete~~s to~~ achieve their optimal performance [1]. In the process of improving an athlete's performance using exercise there is a risk of musculoskeletal injury ~~, the exercises performed must avoid the possibility of harmful factors. One such factor is a musculoskeletal injury~~ [2]. ~~Therefore,~~ ~~the physical capability known as 'F~~flexibility~~'~~ is ~~one of the most~~an important factor~~s~~ for successful performance ~~in such exercise modalities~~ [3]. Previous studies have identified that adequate flexibility is important in both the prevention and rehabilitation of musculoskeletal injuries [4].

Several studies have shown that the exercise method can be an important factor for increasing muscle flexibility in athletes. Kibar et al. observed an eight-week Pilates training program and found it to have a beneficial effect on static balance, flexibility, abdominal muscle endurance, and abdominal and lumbar muscle activity [5]. Previous research conducted by Kathleen et al. explained that the use of a roller-massager could provide statistically significant increases in flexibility, particularly when used for a long duration [6].

Thus, evaluation of flexibility appears to be important for coaches to evaluate their players' flexibility status, predict future performance ~~in exercise or competitions~~, assess injury risk ~~-~~and even detect talented players. According to Wells and Dillon, the sit-and-reach test is a common measure of flexibility, and it specifically measures the flexibility of the lower back and hamstring muscles [7]. Although the sit-and-reach test specifically measures the flexibility of the lower back and hamstring muscles, it is unclear whether this style of test could be performed to assess flexibility in the forward split.~~, And, therefore,~~Therefore, maybe we ~~whether people~~ should adopt new technologies and new variables for measuring flexibility, especially in the forward split.

An interest and motivation behind this study was a comparison with a previous research conducted by Loureiro Jr. et al., who created and developed a new agility test encompassing both perceptual and motor capacity, and an examination of the test's concurrent and construct validity and its test–retest reliability in badminton players [8]. To the best of the authors' knowledge, there is no test that measures specific flexibility in the forward split. Based on the aforementioned problems and interests, the aim of this research was to develop a new flexibility test to examine the forward split in athletes.

Material and methods

In this study, 40 athletes, 15 gymnasts, 10 Taekwondo athletes, 5 football players, and 10 karate athletes, (20 males and 20 females) volunteered to be assessed ontheir ability to

performthe forward split. ~~were evaluated based on the type of exercise they mostly performed: 15 gymnasts, 10 Taekwondo athletes, 5 football players, and 10 karate athletes. They all volunteered to be subjects.~~ All of the participants were asked to fill out a health questionnaire, and they gave their informed consent~~s for their~~to participat~~e~~ion in this study. All the procedures were approved by the ethics committee of the Makassar State University, and the experimental procedure was performed in accordance with the Declaration of Helsinki. The players were between 18 and 20 years old, and they had a minimum continuous training background of five years. Additionally, all athletes must have participated in systemized training, with at least two training sessions per week, each lasting 3 hours. None of the subjects had lower- and upper-extremity injuries or musculoskeletal injuries within six months prior to the initial testing.

Testing setup

The infrared sensor technology (IST) test was performed o~~i~~n a rectangular mattress ~~(area of~~ 8-cm thickness and 2 × 1 m in size~~in width~~). At the centre of the split area was an infrared sensor, placed 4 cm inside the mattress, ~~-~~that provided vertical displacement detection (SHARP GP2Y0A41SK0F distance measuring sensor, 4 to 30 cm). ~~It was placed 4 cm inside the mattress, which is the starting position of the test.~~ Connected ~~with~~ to the infrared sensor was a microcontroller (microchip, model Arduino Uno Atmega328p) programmed in C++ language to ~~control~~ measure the height of the anterior superior iliac spine (ASIS) from the mattress. An automatic light-emitting diode (LED) panel ~~was linked to and also controlled by the microcontroller to~~ displayed the results.

The apparatuses used in the IST test could be considered low cost and efficient for coaches or sports practitioners. The whole apparatus could be built or obtained for less than US$200. Furthermore, the IST test apparatuses could be easily transported and quickly assembled (approximately 15 min) anywhere. The IST is displayed in Figure 1.

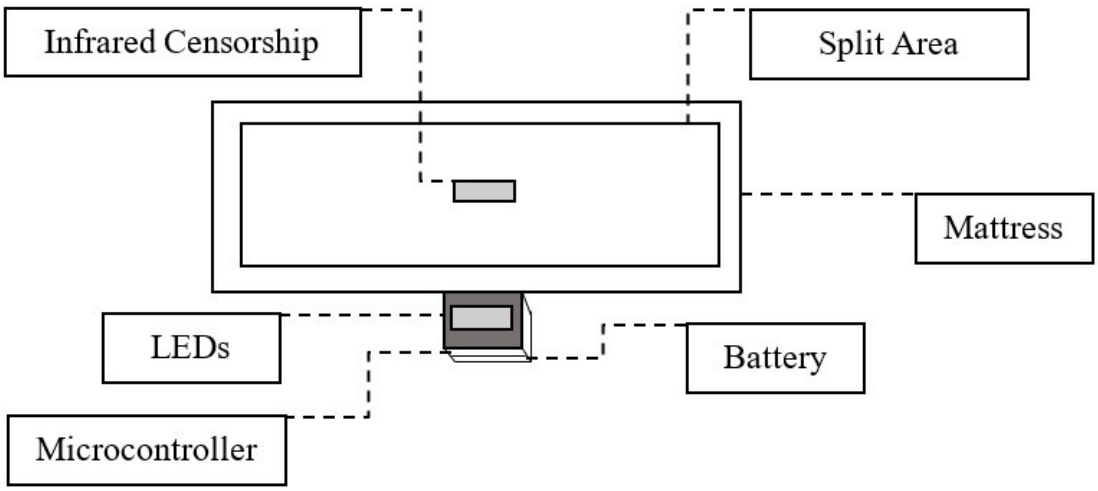

Figure 1. Infrared sensor technology

Experimental overview

The week bBefore the study was performed~~, an~~ anthropometric ~~test~~ mesasurements ~~was carried out in the~~were obtained ~~preceeding week~~. ~~The anthropometric data were measured in athletes' practice sites. Height was measured to the nearest 0.1 cm (Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA) and body mass to the nearest 0.1 kg (Omron Digital Weight Scale HN 289), with participants wearing minimal clothes and being barefoot. The body mass index was calculated as the ratio of the body mass (kilograms) divided by body height (meters) squared.~~ Anthropometric characteristics of the participant's data are shown in Table 1.

Table 1. Anthropometric characteristics of participants

Variable	Female (N = 20)	Male (N = 20)
Age (years) $\overline{X}(SD)$	17.65 (±0.75)	17.80 (±0.77)
Weight (kg) $\overline{X}(SD)$	59.04 (±6.0)	70.56 (±6.06)
Height (cm) $\overline{X}(SD)$	164.23 (±6.13)	170.93 (±8.87)
BMI (kg/m^2) $\overline{X}(SD)$	21.89 (±1.81)	24.24 (±2.35)

~~After the anthropometric measurements,~~T ~~t~~he test was performed at a gymnasium of Makassar State University. The test was divided into two trials, separated by 30-min recovery periods. It was ensured that the participants were wearing the compression garments (CGs).

The CGs used in the test were Sport-Skins Classic whole-body CGs from Skins, Campbelltown, NSW, Australia. The lower-body CGs included long-leg pants (from waist to ankle) composed of 24% ROICA spandex and 76% nylon and Meryl Microfiber [9]. Additionally, sports shoes commonly used in practice sessions were worn by the participants during the testing~~used to perform the tests~~.

Before testing, all athletes ~~had~~ performed a standardized 6-min warm-up period. After the warm-up, participants performed the forward split on the mattress with IST (the IST test), and afterward they performed the forward split on the mattress without IST (the N-IST test)~~: for~~ Trial I. A 5-min rest interval was given to the participants between the performance of the IST and N-IST tests. After ~~each athlete's forward split in~~ Trial I, a 30 min recovery was given before the athlete could perform the forward split in ~~the second trial~~Trial II.

Forward split

The forward split was performed following a previously reported ~~operation~~ procedure [10]. The test was explained and demonstrated step by step to the participants by the experimenter. The participant was asked to start with ~~her or his~~their dominant leg~~ (right or left).~~ In the IST test, the test started when the participant was ready and had placed ~~her or his~~their body in the split area of the mattress. First, the participant was instructed to place the rear leg shank against the vertical side of a gymnastics spotting block. It was assumed that, if the rear leg was placed in this position, it could reduce the variability of the pelvic position as the athletes lowered to their lowest split position. Additionally, this test position helped maintain a pelvis position that kept the frontal plane of the pelvis perpendicular to the line of the forward and rear legs of the forward split. When the participant achieved the lowest split position, the participant gave warning signals, saying 'maximal', and then automatically the infrared sensor controlled the height of the ASIS from the mattress. The administrator noted the results from the LED ~~liquid-crystal~~ displays~~ in the mattress~~. The test ended when the participant finished the lowest split position.

For the N-IST test, participants performed on the mattress without IST. The same protocol for the forward split of the IST test was repeated in the N-IST test. The difference between the N-IST and IST tests was the measurement protocol. In the N-IST test, when the participant achieved the lowest split position, the participant gave warning signals, saying 'maximal'. Then, the administrator palpated the ASIS of the participant and measured the height of the ASIS from the mattress using a meter stick. The forward split test position in IST and N-IST tests is displayed in Figure 2.

Figure 2. (A) Forward split test position in IST test and (B) forward split test position in N-IST test

Statistical Analysis

The values are presented as mean ± SD. A Mann–Whitney U test was used to determine significant or no significant differences between the IST and N-IST tests in two trials. Statistical significance was accepted at the $p < 0.05$ level. The tests were performed by using the SPSS software V.21.0.

Results

Table 2 shows the measurements of the height of the ASIS from the mattress in the N-IST and IST tests. For concurrent validity, no significant difference in the average distances of the ASIS from the mattress in Trial I was found between the IST and N-IST tests ($p = 0.664$). Similar results were found in Trial II, where there was no significant difference between IST and N-IST tests ($p = 0.710$). Furthermore, no significant differences ($p = 0.721$) were observed between the averages of all trials of the IST and N-IST tests.

Table 2. Performance distances of participants in IST and N-IST tests

	Height of the ASIS from the mattress (cm)		p-value
	IST test	N-IST test	
Trial I			
$\overline{X}(SD)$	4.7 (± 3.3)	4.8 (± 3.3)	
Median	4.0	4.0	0.664
Range	0.8 – 11.8	1.0 – 12.0	
Trial II			
$\overline{X}(SD)$	4.5 (± 3.0)	4.6 (± 3.1)	
Median	3.0	4.0	0.710
Range	0.8 – 11.8	1.0 – 12.0	
Average of All Trials			
$\overline{X}(SD)$	4.6 (± 3.1)	4.7 (± 3.2)	
Median	3.9	4.0	0.721
Range	0.8 – 11.7	1.0 – 12.	

Abbreviations:

The values are presented as mean ± SD.

IST, forward split on mattress with infrared sensor technology; N-IST, forward split on mattress without infrared sensor technology; Trial I, measured height of the ASIS from the mattress in first trial; Trial II, measured height of the ASIS from the mattress in second trial; Average All Trials, average of N-IST tests in Trials I and II compared with the average of the IST tests in Trials I and II

Discussion

An attempt was made to develop and examine the specificity of the IST test for the flexibility assessment of athletes. This study showed that measurements in the IST test are strongly related to the measurements by the meter stick. The results of this study showed no significant difference between the IST and N-IST tests. In the study, the meter stick was used as a tool for manual measurement and for comparing the level of similarity of reliability and validity with the IST test. The meter stick was used because this method was considered to have the appropriate reliability and validity to measure the distance; also, the method is often used to measure the forward split. Previous research conducted by William et al. measured the forward-split test in two conditions (vibration and no vibration) using a meter stick, and they used the meter stick for measuring the height of the ASIS from the floor [10].

This study revealed that the sports technology investigated should be created to evaluate an athlete's performances. The evaluation of an athlete's performances is important for increasing and developing the performances of athletes [11]. Several studies have found that sports technology can be used to evaluate an athlete's performance. Loureiro Jr. et al. found a test to evaluate agility in badminton athletes, and it was named the 'Badcamp test'. They explained that the Badcamp test is an effective, valid, and reliable tool to measure agility. The Badcamp test showed that this field test can be used by sports scientists, coaches, and athletic trainers to assess the athletic condition and training effectiveness of badminton players [12].

To the authors' knowledge, coaches or sports scientists have always used a meter stick to measure the height of the ASIS from the mattress in the forward-split test. This method results in a phenomenon that can be a problem. The problem is the parallax error. Parallax error is an error caused by humans while measuring a quantity if the eye is not at the proper angle to the scale of the reading [13]. Because of this problem, the IST was developed to assess flexibility, especially to measure the height of the ASIS from the mattress in the forward-split test and to prevent the parallax error. That is possible because the values are read from the LED display~~the IST has an automatic LED panel that is linked to and also~~

~~controlled by the microcontroller to display the results~~. To the authors' knowledge, there is no digital-based test that evaluates and measures the height of the ASIS from the mattress in the forward-split test. These facts support the notion that the IST provides an accurate test for the forward-split test.

This study has limitations that should be considered. Young athletes with ages between 17 and 19 years were tested. The results could have been different if professional and/or high-level athletes had been evaluated. Therefore, further research using differing subject populations with differing levels of performance is warranted.

Conclusion

The findings of this study confirm the concurrent and construct validity of the IST test, which was created to measure the height of the ASIS from the mattress in a forward-split test. Furthermore, it was shown that the IST test is a valid and reliable instrument to assess flexibility, especially in the forward-split test. Thus, it is recommended that this test be used by coaches, athletes, and sports scientists to improve and monitor training programs in the forward-split testing of athletes.

References

1. Moore TM, Zhou Z, Cohn W, et al. The impact of exercise on mitochondrial dynamics and the role of Drp1 in exercise performance and training adaptations in skeletal muscle. Mol Metab. 2019 Marc;21:51-67.
2. Page P. Current concepts in muscle stretching for exercise and rehabilitation. Int J Sports Phys Ther. 2012 Feb;7(1): 109–19.
3. Johnson AW, Warcup CN, Seeley MK, Eggett D, Feland JB. The acute effect of stretching with vibration on dynamic flexibility in young female gymnastic. J Sports Med Phys Fitness. 2019 Feb;59(2):210-6.
4. Junker DH, Stöggl TL. The Foam Roll as a Tool to Improve Hamstring Flexibility. J Strength Cond Res. 2015 Dec;29(12):3480-5.
5. Kibar S, Yardimci FÖ, Evcik D, Ay S, Alhan A, Manço M, Ergin ES. Can a pilates exercise program be effective on balance, flexibility and muscle endurance? A randomized controlled trial. J Sports Med Phys Fitness. 2016 Oct;56(10):1139-46.

6. Sullivan KM, Silvey DB, Button DC, Behm DG. Roller-massager application to the hamstrings increases sit-and-reach range of motion within five to ten seconds without performance impairments. Int J Sports Phys Ther. 2013 Jun;8(3):228-36.
7. Wells FK, Dillon KE. The Sit and Reach-A Test of Back and Leg Flexibility. Research Quarterly. American Association for Health, Physical Education and Recreation. 2014 Dec;23(1):115-8.
8. Loureiro Jr LFB, De Freitas PB. Development of an agility test for badminton players and assessment of its validity and test-retest reliability. Int J Sports Physiol Perform. 2016 Apr;11(3):305-10.
9. Nguyen TNL, Eager D, Nguyen HT. Effect of Compression Garments on Cardiovascular Function During Recovery Phase. Conf Proc IEEE Eng Med Biol Soc. 2018 Jul;2018:2869-72.
10. William AS, Jeni RM, Michael HSC, Wendy LKA, Gregory HD, Monem J. The effect of vibration on active and passive range of motion in elite female synchronized swimmers. Taylor & Francis. 2008 Jun;8(4):217-23.
11. Liu S, Ritchie J, Sáenz-Moncaleano C, Ward SK, Paulsen C, Klein T, et al. 3D technology of Sony Bloggie has no advantage in decision-making of tennis serve direction: A randomized placebo-controlled study. Eur J Sport Sci. 2017 Jun;17(5):603-10.
12. Loureiro Jr LFB, Costa Dias MO, Cremasco FC, da Silva MG, De Freitas PB. Assessment of Specificity of the Badcamp Agility test for Badminton Players. J Hum Kinet. 2017 Jun 22;57:191-8.
13. Holmin J, Nawrot M. Motion parallax thresholds for unambiguous depth perception. Vision Res. 2015 Oct;115(Pt A):40-7.

REHAB-00062-2019-02 Kotak Masuk

office@advrehab.org 1/8/2019
kepada saya

Dear Bagus Bagus,

the paper was checked by our native speaker and you can find his
comments below:

"This paper needs significant editing by a competent English editor. The
use of wording and phrasing is odd. Many words that have been used are
incorrect and or poorly selected.
While the article in interesting, it needs a significant rewrite."

In order to be published this paper has to be corrected in terms of
language.

kind regards
Anna Ogonowska-Słodownik
Deputy Editor
Advances in Rehabilitation

Decision for manuscript number REHAB-00062-2019-02

Kotak Masuk

Advances in Rehabilitati... 4/9/2019

kepada saya

September 03, 2019
REHAB-00062-2019-02
Infrared Sensor Technology (IST) Test as a Tool for Assessment of Flexibility

Dear Mr. Bagus Bagus,

I am pleased to inform you that your manuscript, entitled: Infrared Sensor Technology (IST) Test as a Tool for Assessment of Flexibility, has been accepted for publication in our journal.
It will be published in number 3/2019.

Thank you for submitting your work to us.

Kind regards,
Bartosz Molik
Editor-In-Chief
Advances in Rehabilitation

Manuscript evaluation is available here:
https://www.editorialsystem.com/rehab/article/162399/view/#showDecisionLetter162399

ADVANCES IN REHABILITATION
POSTĘPY REHABILITACJI

Decision: **accept after changes suggested by reviewer**

June 13, 2019
REHAB-00062-2019-01
Infrared Censorship Technology Test (ICT) As A Tool for Assessment of the Flexibility

Dear Mr. Bagus Bagus,

I am pleased to inform you that your manuscript, entitled: Infrared Censorship Technology Test (ICT) As A Tool for Assessment of the Flexibility, might be accepted for publication in our journal, pending some minor changes suggested by reviewers (see below).

Please revise your paper strictly according to the attached Reviewers' comments. Your manuscript won't be taken into consideration without the revisions made according to the recommendations.

Authors are requested to prepare a revised version of their manuscript as soon as possible. This may ensure fast publication if an article is finally accepted.

Thank you for submitting your work to us.

Kind regards,
Bartosz Molik
Editor-In-Chief
Advances in Rehabilitation

Review 1:

none to disclose

Review 2:

Nicely written text - reads well and clearly.
However, there are some mistakes in the text

1. In line 12 “…Sibel et al, observed an eight-week pilates training” must be corrected as “…Kibar et al, observed an eight-week pilates training”

2. “metre stick” must be corrected as “meter stick”

3. In line 122 “This study showed that measurements in ICT is strongly related to the measurements in metre stick” must be corrected as “This study showed that measurements in ICT are strongly related to the measurements in metre stick”

4 .In the title “Infrared Censorship Technology Test (ICT) As A Tool for Assessment of the Flexibility” must be corrected as “Infrared Censorship Technology Test (ICT) As a Tool for Assessment of the Flexibility”

ADVANCES IN REHABILITATION
POSTĘPY REHABILITACJI

Decision: **accept without changes**

September 03, 2019
REHAB-00062-2019-02
Infrared Sensor Technology (IST) Test as a Tool for Assessment of Flexibility

Dear Mr. Bagus Bagus,

I am pleased to inform you that your manuscript, entitled: Infrared Sensor Technology (IST) Test as a Tool for Assessment of Flexibility, has been accepted for publication in our journal. It will be published in number 3/2019.

Thank you for submitting your work to us.

Kind regards,
Bartosz Molik
Editor-In-Chief
Advances in Rehabilitation

Infrared Censorship Technology Test (ICT) As a Tool for Assessment of the Flexibility

Syahruddin Syahruddin[1,A,F], Imam Safei Imam[2,B-C], Lungit Lungit[2,E], Ramdan Pelana Ramdan[3,E], Bagus Winata Bagus[3,D], Junaidi Junaidi[3,F]

[1]Universitas Negeri Makassar
[2]Universitas Negeri Lampung
[3]Universitas Negeri Jakarta

Received: 2019-05-18
Accepted: 2019-06-16

Abstract:
Introduction: Evaluation of flexibility appears to be important for coaches to check their players' flexibility status, predict future performance in exercise or competitions, and even detect talented players. The aims of this research were to develop a new flexibility test to examine the forward split in athletes.
Material and methods: In this study, we evaluated 40 athletes (20 males and 20 females) from the type of exercise they have mostly performed: (15 gymnasts, 10 Taekwondo, 5 football players and 10 karate athletes) volunteered to be subjects. In the experimental condition participants performed the forward split in mattress with infrared censorship technology (ICT test) and afterward they performed the forward split in mattress without infrared censorship technology (N-ICT test) for trial one.
Results: For concurrent validity, no significant difference in the average distances of the ASIS from the mattress at trial I and II was found between ICT and N-ICT tests ($p=0.664$), ($p=0.710$) respectively.
Conclusions: The findings of this study confirm the concurrent and construct validity of the Infrared Censorship Technology Test (ICT), which was created to measures the height of the ASIS from the mattress in forward split test. Thus, we recommended, for this test could be used by coaches, athletes and sport scientists to improving and monitoring training program in the forward split test of athletes.

Keywords: muscle, athletes, sit and reach, Parallax error, Sports Technology.

Email: fransiskusasisibaguswinata@gmail.com

Introduction

Exercise is the most powerful way of improving the quality of athletes so as to achieve optimal performance [1]. In the process of improving an athlete's performance, exercise must avoid the possibility of harmful factors. One such factor being a musculoskeletal injury [2]. Therefore, the physical capability known as flexibility is one of the most important for successful performance in such exercise modalities [3]. On the other hand, previous studies pointed on the fact that flexibility is important in both the prevention and the rehabilitation of musculoskeletal injuries [4].

Several studies have been observed exercise method can be an important factor for increasing muscle flexibility in athletes. Kibar et al, observed an eight-week pilates training program had been found to have a beneficial effect on static balance, flexibility, abdominal muscle endurance, abdominal and lumbar muscle activity [5]. We were also interested with previous research conducted by Kathleen et al, which explained that the use technical of the roller-massager could provide statistically significant increases in flexibility, particularly when used for a longer duration [6].

Thus, evaluation of flexibility appears to be important for coaches to check their players' flexibility status, predict future performance in exercise or competitions, and even detect talented players. According to Wells and Dillon, the sit and reach test is a common measure of flexibility, and specifically measures the flexibility of the lower back and hamstring muscles [7]. While the sit and reach test has specifically measured for the flexibility of the lower back and hamstring muscles, have this test could be performed to assess flexibility in the forward split? Therefore, that people should adopt new technologies and new variables for measures the flexibility, especially in the forward split.

We were also interested and motivated in comparing with previous research conducted by Loureiro Jr et al, which created and developed a new agility test encompassing both perceptual and motor capacity and to examine the test's concurrent and construct validity and its test-retest reliability in badminton players [8]. To our knowledge, there is no test that measures specific flexibility in the forward split. Based on these problems and interests, the aims of this research were to develop a new flexibility test to examine the forward split in athletes.

Material and methods

In this study, we evaluated 40 athletes (20 males and 20 females) from the type of exercise they have mostly performed: (15 gymnasts, 10 Taekwondo, 5 football players and 10 karate athletes) volunteered to be subjects. All participants were asked to fill out a health

questionnaire and provided informed consent to participate in this study. All of the procedures were approved by the ethics committee of the Makassar State University and the experimental procedure was performed in accordance with the Declaration of Helsinki. The players were between 18 and 20 years old and they've had minimum continuous training background of 5 years. Also, all athletes must have participated in systemized training, with at least 2 training sessions per week, each lasting 3-hour. None of the subjects had lower and upper-extremity injuries or musculoskeletal injuries within 6 months prior to the initial testing.

Testing Setup

The test, which we named Infrared Censorship Technology Test (ICT), is performed in a rectangular mattress area with 8 cm thickness, 2 m in length by 1 m in width. At the center of split area has an infrared censorship that provided vertical displacement detection (SHARP GP2Y0A41SK0F distance measuring sensor 4 to 30 cm) placed 4 cm inside the mattress, which is the starting position of the test. Connected with the infrared censorship is a microcontroller (Microchip, model Arduino Uno Atmega328p) programmed in C++ language to control the height of the ASISfrom the mattress. An automatic LEDs Panel is linked to and also controlled by the microcontroller to display the results.

The apparatuses used in the ICT test could be considered low-cost and efficient for coaches or sports practitioner. The whole apparatus could be built or obtained for less than US $200. Furthermore, the benefits of the ICT test apparatuses are easily transported and quickly assembled (approximately 15 min) anywhere they are to be used. The ICT displayed in Figure 1. The infrared censorship technology displayed in Figure 1.

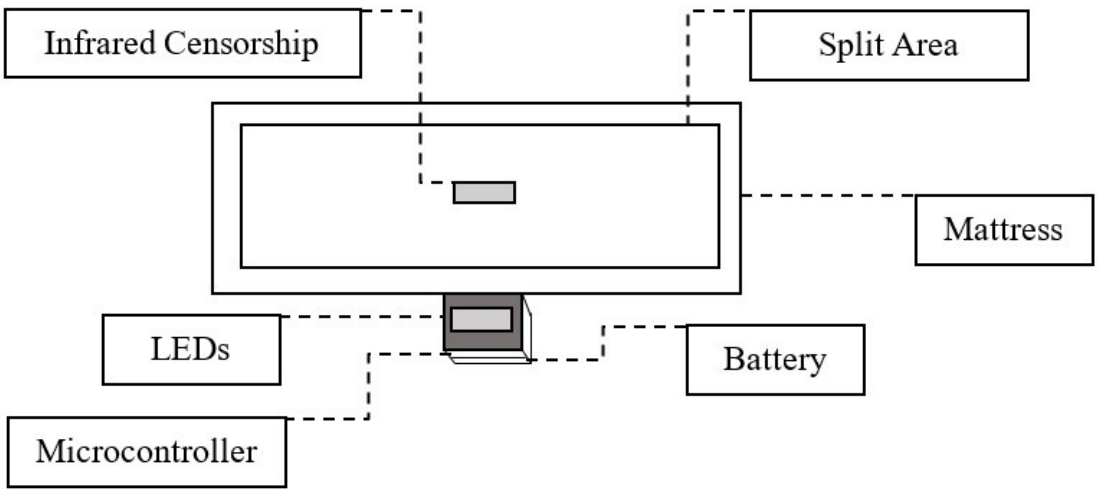

Figure 1. The infrared censorship technology

Experimental overview

Before carrying out the study, the anthropometric test was carried out in the preceding week. Anthropometric was measured in athletes' practice sites. Height was measured to the nearest 0.1 cm (Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA) and body mass to the nearest 0.1 kg (Omron Digital Weight Scale HN 289), with participants wearing minimal clothes and being barefoot. The body mass index was calculated as the ratio of the body mass (kilograms) divided by body height (meters) squared. Anthropometric characteristics of the participant's data are shown in Table 1.

Tab. 1. Anthropometric characteristics of participants

Variable	Female (N=20)	Male (N=20)
Age (years) $\overline{X}(SD)$	17.65 (± 0.75)	17.80 (± 0.77)
Weight (kg) $\overline{X}(SD)$	59.04 (± 6.0)	70.56 (± 6.06)
Height (cm) $\overline{X}(SD)$	164.23 (± 6.13)	170.93 (± 8.87)
BMI (kg/m^2) $\overline{X}(SD)$	21.89 (± 1.81)	24.24 (± 2.35)

After the anthropometric measurements, the test was carried out at gymnasium of Makassar State University. The test divided into two trials, separated by 30-min recovery periods. We were ensured that the participants were wearing the compression garment (CGs). The CGs used in the test was Sport-Skins Classic whole-body compression garments (WBCGs), from Skins, Campbelltown, NSW, Australia. The lower body CGs included long-leg pants (from waist to ankle) which comprised of 24% Roica Spandex and 76% Nylon and Meryl Microfiber [9]. Also, sports shoes commonly used in practice sessions were used to perform the tests.

Before testing, all athletes performed a standardized 6-min warm-up period. After the warm-up, participants performed the forward split in mattress with infrared censorship technology (ICT test) and afterward they performed the forward split in mattress without infrared censorship technology (N-ICT test) for trial one. A five-minute rest interval was given to the participants between the performance of the ICT test and N-ICT test. After each player's forward split in trial one, recovery was given before they were allowed to perform the forward split in the second trial.

Forward split

Forward split following our previous operation [10]. The test was explained and demonstrated step by step to the participants by the experimenter. The participant was asked to start with their leg dominance (right or left). In the ICT test, the test started when the participant was ready and placing their body in split area of mattress. Firstly, participant was instructed for placing their rear leg shank against the vertical side of a gymnastics spotting block. We assumed, if the rear leg was placed in this position could reduce the variability of pelvic position as the athletes lowered to their lowest split position. Also, this test position helps maintain a pelvis position that keeps the frontal plane of the pelvis perpendicular with the line of the forward and rear legs of the forward split. When the participant achieved their lowest split position, participant should gave warning signals, saying “maximal” and then automatically the infrared censorship will control the height of the ASIS from the mattress. The administrator should take noted the results from LCDs in mattress. The test ended when the participant finished their lowest split position.

For the N-ICT test, participants should perform in mattress without infrared censorship technology. The same protocol forward split of ICT test was repeated in N-ICT test. The difference between N-ICT test and ICT test is the measurement protocol. That could be explained, when the participant achieved their lowest split position, the participant should give warning signals, saying “maximal”. And then the administrator should palpate the ASIS of the participant and measured the height of the ASIS from the mattress using a meter stick. The forward split test position in ICT and N-ICT tests displayed in Figure 2.

Figure 2. (A) The forward split test position in ICT test; (B) The forward split test position in N-ICT test

Statistical Analysis

The values are presented as mean ± SD. A Mann Whitney U Test was used to determine significant or no significant differences among the ICT test and N-ICT test on two

trials. Statistical significance was accepted at the $p<0.05$ level. Performed by using the SPSS software, V.21.0.

Results

Table 2 shows the height of the ASIS from the mattress measures in the N-ICT and ICT tests. For concurrent validity, no significant difference in the average distances of the ASIS from the mattress at trial I was found between ICT and N-ICT tests (p=0.664). The similar results were found in trial II, there was no significant difference between ICT and N-ICT tests (p=0.710). Furthermore, no significant differences (p=0.721) were observed between average all trials of ICT and N-ICT tests.

Tab. 2. Performance distances of participants in ICT and N-ICT tests

	Height of the ASIS from the mattress (cm)		p-value
	ICT test	N-ICT test	
Trial I			
$\overline{X}(SD)$	4.7 (± 3.3)	4.8 (± 3.3)	
Median	4.0	4.0	0.664
Range	0.8 – 11.8	1.0 – 12.0	
Trial II			
$\overline{X}(SD)$	4.5 (± 3.0)	4.6 (± 3.1)	
Median	3.0	4.0	0.710
Range	0.8 – 11.8	1.0 – 12.0	
Average All Trials			
$\overline{X}(SD)$	4.6 (± 3.1)	4.7 (± 3.2)	
Median	3.9	4.0	0.721
Range	0.8 – 11.7	1.0 – 12.	

Abbreviations:

The values are presented as mean ± SD.

ICT, forward split in mattress with infrared censorship technology; N-ICT, forward split in mattress without infrared censorship technology; Trial I, measured height of the ASIS from the mattress in first trial; Trial II, measured height of the ASIS from the mattress in second trial; Average All Trials, average of N-ICT test in trial I and trial II compared with average of ICT test in trial I and trial II

Discussion

We aimed with this study to develop and to examine the specificity of the Infrared Censorship Technology Test (ICT) test for the flexibility assessment of athletes. This study showed that measurements in ICT are strongly related to the measurements in meter stick (N-CT). On the fact that in the results of this study showed no significant between ICT and N-ICT tests. In our study, we used meter stick as a tool for a manual measurement and for compared the level of similarity of reliability and validity with the ICT test. We used meter stick because this method considered to have the right reliability and validity to measure a

distance, also the method is often used to make measure on the forward split. Previous research conducted by William et al, measured the forward split test in two conditions (vibration and no vibration) using a meter stick, they were used the meter stick for measures height of the ASIS from the floor [10].

This study revealed that the sports technology should be create to evaluate an athlete's performances. The evaluation of an athlete's performances appears to be important for increasing and developing performances in athletes [11]. A number of studies have found that the sports technology has been created to evaluate an athlete's performances. Loureiro Jr et al, found a test to evaluate agility in badminton athletes, which was named Badcamp test. They were explained that Badcamp test is an effective, valid and reliable tool to measure agility. Badcamp test have been shown that this field test can be used by sport scientists, coaches and athletic trainers to assess athletic condition and training effectiveness of badminton players [12].

To our knowledge, coaches or sport scientists always use meter stick to measures the height of the ASIS from the mattress in forward split test. In this method have a phenomenon that can be a problem. The problem is parallax error. Parallax error is an error caused by humans, while measuring a quantity if the eye is not at the proper angle to the scale of the reading [13]. Based on these problems, ICT was developed to assess flexibility, especially to measures the height of the ASIS from the mattress in forward split test and to prevent the parallax error. That is possible, because ICT have an automatic LEDs Panel is linked to and also controlled by the microcontroller to display the results. To our knowledge, there is no test digital based that evaluate and measures the height of the ASIS from the mattress in forward split test. Those facts support the notion that the ICT is a specific test for forward split test.

This study has limitations that should be considered. We tested young athletes with age between 17 and 19 years. The results could have been different if professional and/or high-level players had been evaluated. Therefore, further research using differing subject populations, differing level performance is warranted.

Conclusion

The findings of this study confirm the concurrent and construct validity of the Infrared Censorship Technology Test (ICT), which was created to measures the height of the ASIS from the mattress in forward split test. Furthermore, we have shown that the ICT test is a valid and reliable instrument to assess flexibility, especially in the forward split test. Thus, we

recommended, for this test could be used by coaches, athletes and sport scientists to improving and monitoring training program in the forward split test of athletes.

References

1. Moore TM, Zhou Z, Cohn W, et al. The impact of exercise on mitochondrial dynamics and the role of Drp1 in exercise performance and training adaptations in skeletal muscle. Mol Metab. 2019 Marc;21:51-67.
2. Page P. Current concepts in muscle stretching for exercise and rehabilitation. Int J Sports Phys Ther. 2012 Feb;7(1): 109–19.
3. Johnson AW, Warcup CN, Seeley MK, Eggett D, Feland JB. The acute effect of stretching with vibration on dynamic flexibility in young female gymnastic. J Sports Med Phys Fitness. 2019 Feb;59(2):210-6.
4. Junker DH, Stöggl TL. The Foam Roll as a Tool to Improve Hamstring Flexibility. J Strength Cond Res. 2015 Dec;29(12):3480-5.
5. Kibar S, Yardimci FÖ, Evcik D, Ay S, Alhan A, Manço M, Ergin ES. Can a pilates exercise program be effective on balance, flexibility and muscle endurance? A randomized controlled trial. J Sports Med Phys Fitness. 2016 Oct;56(10):1139-46.
6. Sullivan KM, Silvey DB, Button DC, Behm DG. Roller-massager application to the hamstrings increases sit-and-reach range of motion within five to ten seconds without performance impairments. Int J Sports Phys Ther. 2013 Jun;8(3):228-36.
7. Wells FK, Dillon KE. The Sit and Reach-A Test of Back and Leg Flexibility. Research Quarterly. American Association for Health, Physical Education and Recreation. 2014 Dec;23(1):115-8.
8. Loureiro Jr LFB, De Freitas PB. Development of an agility test for badminton players and assessment of its validity and test-retest reliability. Int J Sports Physiol Perform. 2016 Apr;11(3):305-10.
9. Nguyen TNL, Eager D, Nguyen HT. Effect Of Compression Garments On Cardiovascular Function During Recovery Phase. Conf Proc IEEE Eng Med Biol Soc. 2018 Jul;2018:2869-72.
10. William AS, Jeni RM, Michael HSC, Wendy LKA, Gregory HD, Monem J. The effect of vibration on active and passive range of motion in elite female synchronized swimmers. Taylor & Francis. 2008 Jun;8(4):217-23.
11. Liu S, Ritchie J, Sáenz-Moncaleano C, Ward SK, Paulsen C, Klein T, et al. 3D technology of Sony Bloggie has no advantage in decision-making of tennis serve

direction: A randomized placebo-controlled study. Eur J Sport Sci. 2017 Jun;17(5):603-10.

12. Loureiro Jr LFB, Costa Dias MO, Cremasco FC, da Silva MG, De Freitas PB. Assessment of Specificity of the Badcamp Agility test for Badminton Players. J Hum Kinet. 2017 Jun 22;57:191-8.
13. Holmin J, Nawrot M. Motion parallax thresholds for unambiguous depth perception. Vision Res. 2015 Oct;115(Pt A):40-7.