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Impact of Decreased Hamstring Flexibility and Trunk Muscle Strength Performance in Junior Badminton Athletes with a History of Knee Injuries: The Risk of Low Back Pain

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Abstract This study investigated the correlation of hamstring flexibility of athletes affected by knee injuries, with variable trunk muscle strength (TMS) as one of the indicators of low back pain (LBP) in badminton athletes. This cross-sectional study recruited 120 junior badminton athletes, including males and females (n = 60 each). In each gender category, these athletes were divided into two categories based on injury history: athletes with a history of knee injuries (n = 30) and those without a history of knee injuries (n = 30). The knee injury screening test comprised a visual analog scale (VAS) and anterior knee pain scale (AKPS). Hamstring flexibility and TMS were measured using a Takei Flexion-D digital anteflexion meter and a Takei Back-A analog back muscle dynamometer, respectively. Two-way Analysis of Variance (ANOVA) showed a significant main effect based on injury history on VAS (p = 0.001; F = 96.628; ES = 0.454 [small]) and AKPS (p = 0.007; F = 108,538; ES = 0.483 [small]). The AKPS in males [r = -0.575, p = 0.001] and females [r = -0.304, p = 0.018] showed a negative correlation with flexibility. The Spearman correlation also showed a negative correlation between AKPS and TMS in males [r = -0.227, p = 0.082] and females [r = -0.354, p = 0.006]. This study showed that the AKPS is negatively correlated with flexibility and TMS performance, indicating an increased risk of LBP in the future.

Keywords Injury Risk, Knee, Performance, Prevention, Racquet Sports, Sport Injuries

1. Introduction

Explosive movements in badminton, such as lunges, jumping, and rapid changes in direction, can cause inadequacy in any segment or joint area, thereby increasing the risk of asymmetry and dysfunction in certain areas [1]. Previous literature has revealed that badminton contributes 1-5% of all sports injuries [2]. This shows that although badminton is a noncontact sport, the risk of injury is still present and cannot be avoided [3]. Therefore, some researchers have conducted retrospective injury studies to assist badminton practitioners in carrying out preventive injury measures [4, 5].

In general, the study of retrospective injury badminton provides conclusions about injury rates (IR) per 1000 h such that one hour is defined as one sport participation by one athlete [4, 5]. For example, Jorgensen et al. [4] reported that injuries to badminton were 2.9 injuries per 1000 playing hours, with a specification of 58% of injuries occurring in the lower limb. Conversely, Goh et al. [5] in an observational study revealed that 40% of the total 42 lower limb injuries were knee injuries, while the second most common was back pain injuries with 38% of the 42 lower limb cases.

Knee injuries and low back pain (LBP) can be classified as incident injuries due to overuse [6]. Many previous studies have evaluated this phenomenon from biomechanical [7, 8] or epidemiological analysis [9-11]. In general, experts have concluded that knee injuries and LBP are interrelated injuries and are caused by several factors, such as decreased hamstring flexibility [9], weakening of the abdominal muscles and shortening that cause instability of the hip flexor muscle [10], and low trunk muscle strength (TMS) [11].

Feldmen et al. [9] carried out a review analysis concluding that reduced hamstring flexibility was a risk factor for the development of LBP. Mullaney et al. [12] confirmed that knee injuries, specifically patellofemoral pain (PFP) syndrome, could be closely associated with inflexible hamstrings. From these two studies, it can be concluded that hamstring flexibility has a strong correlation with the occurrence of knee injuries and LBP [9, 12, 13]. Therefore, it is possible that if a person experiences knee injuries caused by an inflexible hamstring, the risk of developing LBP increases.

Although researchers have shown concern for knee injuries and LBP analysis in badminton athletes [14, 15], the analysis is still limited when compared with those in studies of racquet sports [16, 17] or epidemiological cases in other sports [18]. Furthermore, to the best of our knowledge, no cross-sectional study has explained the relationship between hamstring flexibility in athletes who have been affected by knee injuries and the correlation of possible risks to LBP in the future. Therefore, we investigated the correlation of hamstring flexibility in athletes with knee injuries, with TMS as one of the indicators of LBP occurrence in badminton athletes.

2. Materials and Methods

2.1. Participants

In this cross-sectional study, 120 junior badminton athletes (age range: 17–19 years), including males and females (n = 60 each), were recruited. Among them, 37 athletes were ranked within the top 200 according to the Badminton World Federation (BWF). In each gender category, these athletes were divided into two categories: athletes with a history of knee injuries (n = 30) and those without a history of knee injuries (n = 30). All participants were enrolled and recruited into the study based on the following criteria: registered as a badminton junior academy player with a training history of 15 h/week, has participated in a minimum national competition, does not smoke, has no concomitant diseases, and does not use any anti-inflammatory or antioxidant drugs. For athletes with a history of knee injuries, inclusion criteria are as follows: must show a physician's certificate explaining the history of knee injuries and be declared cured 6 months before the start of this study. Athletes without a history of knee injuries are required to show a physician's certificate stating that they have never experienced a history of knee injuries during their time as junior badminton athletes and are free from any injuries 6 months prior to this study. Additionally, players who have a history of LBP were excluded from the study. This research has passed the ethical committee test based on the Declaration of Helsinki and has been approved by the ethics committee of the POLTEKKES Bandung (09/KEPK/EC/III/2021). This study has been conducted with the informed consent of all participants.

2.2. Design

All participants were divided based on their respective gender criteria and history of knee injuries. Patients with a history of knee injuries were recruited for a single-blind randomized evaluation of the correlation between hamstring flexibility and TMS on knee and back pain injuries. This study was divided into two measurement categories: screening athlete injuries and hamstring flexibility and TMS measurements. The knee injury screening test was carried out by all participants by filling in the visual analog scale (VAS) and anterior knee pain scale (AKPS). Hamstring flexibility and TMS were measured using a Takei Flexion-D digital anteflexion meter (T.K.K.5403, Takei Scientific Instruments Co. Ltd., Niigata, Japan) and a Takei Back-A analog back muscle dynamometer (T.K.K.5002, Takei Scientific Instruments Co. Ltd.), respectively. This entire series of studies were carried out for four days, between October 31, 2021 and November 3, 2021, involving professional therapists (n = 4) to conduct screenings related to the injury history of each player and technical badminton coaches (n = 4) for flexibility assessment and TMS of each participant. The professional therapists and technical coaches were blinded to the details of the assessments and data analyses. The final analysis was performed by professional sports biomechanics in badminton (n = 2), professional sports physiology in badminton (n = 1), and orthopedic surgeon knees (n = 1), who were also blinded to the hamstring flexibility and TMS assessment of the enrolled participants. The research design is illustrated in Figure 1.

2.3. Flexibility and TMS Measurements

All participants took measurements of flexibility tests first followed by TMS. Both the measurements were performed for an interval of 5 min to allow the muscles to recover. Before performing the measurements, all participants were required to perform anthropometric measurements. The Omron HN 289 digital weight scale was used to measure body weight. In this section, all the participants wore only thin pants and were barefoot. We used a Seca 214 portable stadiometer (Cardinal Health Dublin, USA) to determine the subjects' body height following the established procedures. Body mass index (BMI) was calculated as body mass (kg) divided by the square of body height (m). Measurements were carried out indoors at a temperature of 25 ℃ and humidity of 70-80%. The participants were asked to conduct a familiarization test before starting the measurement.

For flexibility measurements, participants were asked to stand on a Takei Flexion-D digital anteflexion meter box with their knees perpendicular. The administrator officer ensures that the liquid crystal display (LCD) shows the number "0-cm". After everything was declared ready, the participants were asked to perform body bending in the forward direction to the maximum, while pushing the LCD of the Takei Flexion-D digital anteflexion meter to the maximum using fingertips. Participants were not allowed to bend their knees when body bending in the forward direction was performed. The results were obtained based on the distance from the "0-cm" point displayed on the LCD up to the maximum distance when participants performed body bending in the forward direction, with a minimum measurement unit of 0.1 cm.

For TMS measurements, participants were asked to stand on a Takei Back-A analog back muscle dynamometer box with knees bent at 45 ° with a perpendicular trunk position. The administrator officer ensured that the LCD showed a point of "0-kg," and the position of the handlebar height was above the knee and did not exceed the height of each participant's hip. In TMS measurements, the position of the hip flexion angle was 35 °, and the knee angle flexion was 45 °. These angles were measured by the administrator before the start of the test using a goniometer. Once all participants were declared ready, they were asked to pull up the handlebar as hard as possible. The results were obtained based on the maximum ability of the participants indicated by the LCD of the Takei Back-A analog back muscle dynamometer, with a minimum measurement unit of 1 kg. In this study, all participants underwent two attempts at each measurement, and the best results were obtained.

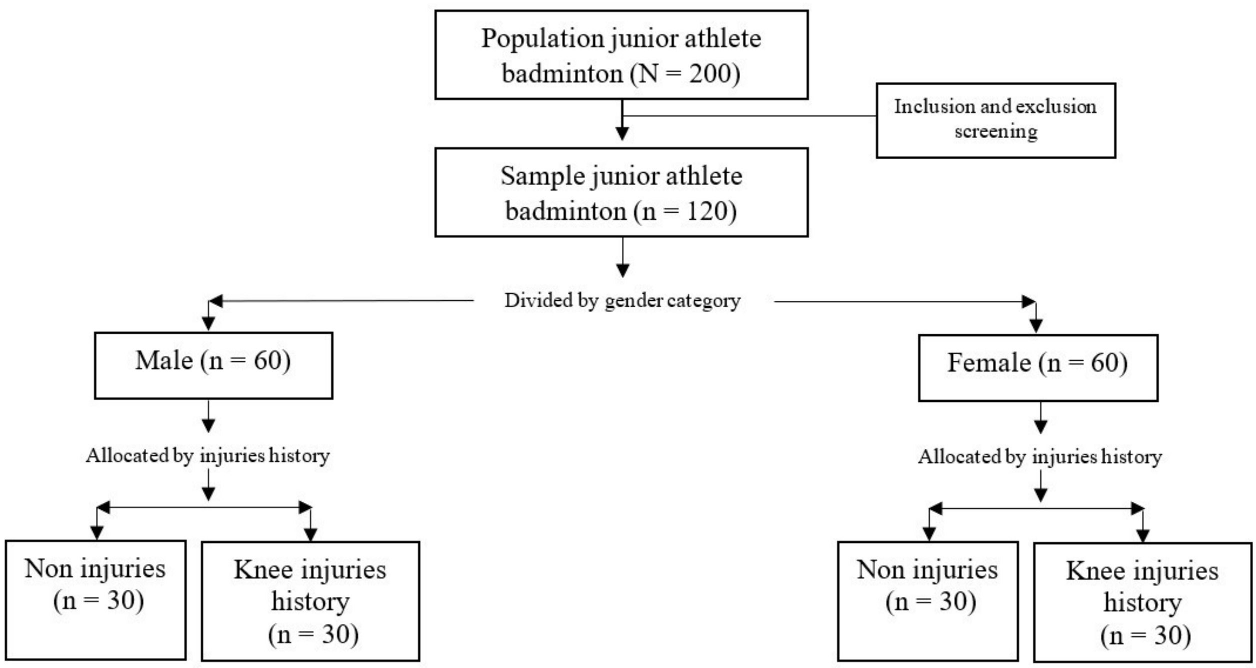

Figure 1. Research design

2.4. Visual Analog Scale (VAS) and Anterior Knee Pain Scale (AKPS) Questionnaires

VAS and AKPS questionnaires were adopted based on previous studies [19, 20]. All participants were given a more detailed explanation of the VAS and AKPS during the familiarization session, thus ensuring that each participant understood the purpose of the two questionnaires. In the VAS test, the participants were required to assess their knee pain. The VAS includes 0–10 points, where 0 indicates no pain and 10 indicates the worst possible pain. In the AKPS measurements that measure pain and function in the knee, there are 13 that must be answered by each participant, where a total score on the AKPS ranges from 0 to 100, with lower scores indicating greater disability. All questionnaire results were presented to two administrators who were blinded to the knee injury history of the enrolled patients. After collection, the data were analyzed by professional sports physiology in badminton (n = 1) and orthopedic knee surgeons (n = 1).

2.5. Statistical Analysis

Statistical analysis was performed using IBM SPSS software version 25.0. All data were tested normally using the Shapiro–Wilk test and Levene's statistics. An independent t-test was used to determine the differences in the anthropometric characteristics of all participants based on gender and injury history. Two-way Analysis of Variance (ANOVA) (gender × injury history) was used to reveal the differences in the results of each parameter. Confidence intervals (95% CI) were calculated to indicate the magnitude of change. Effect size (ES) was calculated and defined as follows: trivial, <0.19; small, 0.2-0.49; medium 0.5-0.79; large, >0.8. Correlation test between VAS and AKPS questionnaires, with variable flexibility and TMS in male and female using Spearman's correlation test. In the Spearman's correlation test, a r_s of +1 indicates a perfect positive correlation between variables, r_s of –0.9, –0.8, and –0.7 indicates a strong correlation between variables, r_s of –0.6, –0.5, and –0.4 indicates a moderate correlation between variables, r_s of -0.3, -0.2, and -0.1 indicates a weak correlation between variables, and 0 indicates a zero correlation between variables. Statistical significance was set at $p < 0.05$.

3. Results

Table 1 displays the anthropometric characteristics of all participants based on gender and injury history. The t-test independence showed no difference between players in the male group [age, p = 0.292; weight, p = 0.342; height, 0.117; BMI, p = 0.162; body fat, p = 0.864; experience, p = 0.186]. The characteristic results in the male group were also linear with the characteristics in the female group [age, p = 0.325; weight, p = 0.054; height, p = 0.269; BMI, p = 0.089; body fat, p = 0.243; experience, p = 0.259].

3.1. Two-Way ANOVA Results

Two-way ANOVA showed that there was a significant main effect based on injury history in VAS (p = 0.001; F = 96.628; ES = 0.454 [small]), AKPS (p = 0.007; F = 108,538; ES = 0.483 [small]), flexibility (p = 0.067; F = 62,602; ES = 0.351 [small]), and TMS (p = 0.001; F = 15,764; ES = 0.120 [trivial]). From a gender perspective, ANOVA showed the same results, with significant results for each variable: VAS [p = 0.001; F = 22,993; ES = 0.165 (trivial)], AKPS [p = 0.001; F = 7,541; ES = 0.061 (trivial)], flexibility [p = 0.001; F = 3,431; ES = 0.029 (trivial)], and TMS [p = 0.001; F = 93,748; ES = 0.447(small)]. There was a significant correlation between injury history and gender as shown by ANOVA in the variable AKPS [p = 0.015; F = 6,046; ES = 0.050 (trivial)]. Conversely, there was no significant correlation between injury history and gender on the VAS (p = 0.340; F = 0.920; ES = 0.008 [trivial]), flexibility (p = 0.878; F = 0.024; ES = 0.001 [trivial]), and TMS (p = 0.635; F = 0.227; ES = 0.002 [trivial]). See Table 2 for details of differences in non-injury and injury history of athletes on each variable measurement.

Table 1. Characteristics of the sample by gender and injury history

Variables	Male Players Non-Injuries ($\bar{X} \pm SD$)	Male Players Injuries ($\bar{X} \pm SD$)	*p*-Value	Female Players Non-Injuries ($\bar{X} \pm SD$)	Female Players Injuries ($\bar{X} \pm SD$)	*p*-Value
Age (years)	18.4 ±0.50	18.3 ±0.47	0.292	18.3 ±0.47	18.4 ±0.57	0.325
Weight (kg)	62.54 ±9.96	57.72 ±8.10	0.342	56.36 ±8.78	51.53 ±10.18	0.054
Height (cm)	170.4 ±7.16	167.4 ±7.49	0.117	160.1 ±4.08	154.7 ±26.61	0.269
BMI (kg/m^2)	21.54 ±2.51	20.6 ±2.62	0.162	21.93 ±2.90	20.5 ±3.29	0.089
Body fat (%)	14.82 ±3.65	14.98 ±3.56	0.864	24.35 ±3.46	23.15 ±4.37	0.243
Experience (years)	10.2 ±0.94	9.9 ±0.99	0.186	9.9 ±1.31	10.3 ±1.44	0.259

Statistical analysis with independent t-test

Table 2. Differences in non-injury and injury history of athletes on VAS, AKPS, flexibility, and TMS

Variables	Non-injuries		Injuries		*p*-Value		
	Male ($\bar{X} \pm SD$)	Female ($\bar{X} \pm SD$)	Male ($\bar{X} \pm SD$)	Female ($\bar{X} \pm SD$)	Injury History	Gender	Injuries History x Gender
VAS	1.3 ±0.7	0.5 ±0.6	2.5 ±0.6	2.0 ±1.1	0.001**	0.001**	0.340
AKPS	21.0 ±6.3	20.4 ±10.4	46.4 ±6.9	36.1 ±16.4	0.007*	0.001**	0.015*
Flexibility	20.8 ±3.6	21.9 ±2.8	15.5 ±3.4	16.8 ±4.4	0.067*	0.001**	0.878
TMS	145.5 ±19.1	118.1 ±18.0	135.1 ±15.9	104.9 ±11.0	0.001**	0.001**	0.635

VAS, visual analog scale; AKPS, anterior knee pain scale; TMS, trunk muscle strength

Statistical analysis with 2 × 2 repeated measures ANOVA

*Statistically significant differences between non-injuries and injuries ($p < 0.05$)

**Statistically significant differences between non-injuries and injuries ($p < 0.001$)

3.2. Spearman Correlation Test Results

The comparisons among VAS, AKPS, flexibility, and TMS were assessed using the Spearman correlation test. Specifically, Table 3 shows the correlation of VAS, AKPS, flexibility, and TMS in general. Tables 4 and 5 show the correlation of VAS, AKPS, flexibility, and TMS by gender in males and females, respectively. In general, there was a correlation of strong positive outcomes between the VAS and AKPS [r = 0.763, p = 0.001] as well as flexibility and TMS [r = 0.070, p = 0.446]. The results of pain in knee measurements measured using the VAS were significantly different and moderately negatively correlated with flexibility ability [r = -0.404, p = 0.001]. However, there was moderate positive correlation between the VAS and TMS ability in all participants [r = 0.052, p = 0.572]. Conversely, AKP showed a moderate negative correlation and a significant difference in flexibility ability [r = -0.427, p = 0.001] as well as a perfect negative correlation but did not differ significantly from TMS performance [r = -1.02, p = 0.268].

Table 3. Total data correlation test results

	Spearmen r	*p*-Value
VAS		
AKPS	0.763	0.001**
Flexibility	−0.404	0.001**
TMS	0.052	0.572
AKPS		
Flexibility	−0.427	0.001**
TMS	−1.02	0.268
Flexibility		
TMS	0.070	0.446

VAS, visual analog scale; AKPS, anterior knee pain scale; TMS, trunk muscle strength

Statistical analysis with spearman correlation

*Statistically significant differences between non-injuries and injuries ($p < 0.05$)

**Statistically significant differences between non-injuries and injuries ($p < 0.001$)

Table 4. Spearman correlation test results among VAS, AKPS, flexibility, and TMS for injured versus healthy males

	Spearmen r	*p*-Value
VAS		
AKPS	0.737	0.001**
Flexibility	−0.512	0.001**
TMS	0.024	0.858
AKPS		
Flexibility	−0.575	0.001**
TMS	−0.227	0.082
Flexibility		
TMS	0.156	0.234

VAS, visual analog scale; AKPS, anterior knee pain scale; TMS, trunk muscle strength

Statistical analysis with spearman correlation

*Statistically significant differences between non-injuries and injuries ($p < 0.05$)

**Statistically significant differences between non-injuries and injuries ($p < 0.001$)

Table 5. Spearman correlation test results among VAS, AKPS, flexibility, and TMS for injured versus healthy females

	Spearmen r	*p*-Value
VAS		
AKPS	0.833	0.001**
Flexibility	−0.342	0.007*
TMS	−0.426	0.001**
AKPS		
Flexibility	−0.304	0.018*
TMS	−0.354	0.006**
Flexibility		
TMS	0.352	0.006**

VAS, visual analog scale; AKPS, anterior knee pain scale; TMS, trunk muscle strength

Statistical analysis with spearman correlation

*Statistically significant differences between non-injuries and injuries ($p < 0.05$)

**Statistically significant differences between non-injuries and injuries ($p < 0.001$)

More specifically, the Spearman correlation test also measured each variable based on gender. In males, a strong positive correlation and significant differences were observed in VAS and AKPS scores [r = 0.737, p = 0.001]. In addition to the questionnaire, a perfect positive correlation was also observed in performance measurements between flexibility and TMS [r = 0.156, p = 0.234]. Concurrently, VAS and flexibility showed a significant moderate negative correlation [r = -0.512] at a significantly different level [p = 0.001]. The opposite result was shown between VAS and TMS, where the Spearman correlation test showed a zero positive correlation between the two [r = 0.024, p = 0.858]. Conversely, AKPS shows a moderate negative correlation and a weak negative correlation in flexibility ability [r = -0.575, p = 0.001], and TMS ability [r = -0.227, p = 0.082], respectively. Because of this fact, the statistical analysis confirms that there was a relationship between hamstring flexibility athletes, with the variable TMS as one of the indicators of the occurrence of LBP, especially in male athletes.

In females, a strong positive correlation with significant differences was found in the questionnaire measurements between VAS and AKPS [r = 0.833, p = 0.001] as well as a weak positive correlation in the performance measurements between flexibility and TMS [r = 0.352, p = 0.006]. A negative correlation was found between the results of the questionnaire and the results of the performance measurements. VAS scores were weak and negatively correlated with flexibility [r = -0.342, p = 0.007] and moderate negative correlated with TMS [r = -0.426, p = 0.001] performance. Conversely, AKPS also had a weak negative correlation with flexibility [r = -0.304, p = 0.018] and TMS [r = -0.354, p = 0.006] performance. This further strengthens the conclusion that in women, there was also a relationship between hamstring flexibility athletes and TMS as indicators of the occurrence of LBP.

4. Discussion

This study investigated the correlation of hamstring flexibility in athletes affected by knee injuries, using TMS as an indicator of the occurrence of LBP in badminton athletes. To the best author's knowledge, there was no cross-sectional study has explained the relationship between hamstring flexibility in athletes, who have been affected by knee injuries and the correlation of possible risks to LBP in the future. Consequently, this study revealed several results: (1) In the flexibility test, female players have better flexibility than male players. (2) There was a positive correlation between AKPS and VAS in reflecting the level of pain and knee function in badminton players. (3) AKPS has a negative correlation with hamstring flexibility and TMS performance, which indicates that there was a tendency to correlate hamstring inflexibility with LBP risk in the future. This research can add to several previous studies on injuries among badminton players to educate athletes and badminton coaches on injury prevention.

This study supports several previous studies that have addressed epidemiological injuries in badminton athletes [9-11, 21, 22]. For example, although this study only focused on knee and LBP injuries, it aimed to reveal that both injuries are the most common types of injuries [6-11]. Yung et al. [21] revealed that 50% of the total injuries in badminton occur in the lower limbs, especially knee injuries. Subsequently, Kaldau et al. [22] performed an injury classification based on anatomical location and found that the knee (n = 28), ankle (n = 19), and lower back (n = 10) were the predominantly injured regions in 104 badminton players.

The current study demonstrated that flexibility performance is one of the factors that may play a significant role in the occurrence of injuries [9]. This awareness is in line with the study of Chandler et al., [23] who explained that the physical demands of sports performance on the athlete's body cause certain musculoskeletal adaptations. The lack of flexibility in athletes will cause maladaptation, reduce the joint range of motion, change biomechanical patterns, and decrease the efficiency of force production, thereby increasing the risk of injury to be even greater [23]. This concern seems to occur in badminton, considering that there are many repetitive movements, such as lunges, jumps, or other explosive movements, allowing microtrauma to the tight muscles in badminton players [24]. Furthermore, if this is left without good flexibility, the risk of injury to badminton athletes may increase.

In this study, flexibility was found to be better in female than in male athletes. Moreover, previous literature has explained that, in general, women have better flexibility than men because women's muscle mass is smaller than that of men's and women have greater vasodilatation than men [25]. The results of the difference in flexibility between male and female players here, as well as the previous theory that decreasing flexibility may cause the risk of injury to be even greater, are in line with previous epidemiological studies [26]. Pardiwala et al. [26] reported that male players were more frequently injured than female players, with a prevalence of injuries of 0.3 injuries per player. Although the study did not measure concretely the correlation of flexibility with injuries in male and female players, the findings in this study may help illustrate the correlation between flexibility ability and the risk of injury in female and male players, consistent with that of previous studies. Future studies are needed to clarify the relationship between flexibility and risk of injury in female and male players.

In this study, the AKPS and VAS were used to determine the level of knee pain. Specifically, the results of this study show a positive correlation between the two variables in determining the level of knee pain in badminton players. The results of this study are consistent with those of several previous studies [19, 27]. For example, Hott et al. [19] revealed that the AKPS has reliability and construct validity in the PFP. The conclusions of the study of Hott et al. [19] were obtained by testing the validity of the AKPS with several other comparator instruments, such as VAS, knee self-efficacy score (K-SES), EQ5D-5L anxiety/depression, and the Hopkins Symptom Checklist (HSCL-10). Although it is understood that there have been no badminton studies that use the AKPS and VAS at the same time, we can encourage sports practitioners that the positive correlation between the two variables can be used in badminton athletes.

However, the risk of injury experienced by badminton players is a concern in this study. Several previous studies have analyzed how the mechanism of injury can occur in badminton, even though it is a noncontact sport [3-5]. Kimura et al. [3] described how anterior cruciate ligament (ACL) injuries occur in badminton athletes. The study explained that, in general, ACL occurs due to a single-leg landing when performing an overhead or jump smash stroke. The study states that during single-leg landing, the knee valgus moment opposite the dominant hand side of the racket can be created larger when landing on court [3]. This increase in knee valgus is a factor in the increased risk of ACL injury in badminton athletes [28]. By examining the results revealed by Kimura et al., [3] expectedly, ACL or other knee injuries are more dominant than other injuries, considering the recent research revealed that single-leg landings after an overhead stroke (520) accounted for about 21.07% of all badminton game events (2468).

There was a correlation between athletes' hamstring flexibility and the risk of knee injuries [12, 13, 29]. Lee et al. [13] confirmed that inflexibility of the hamstring can increase the risk of PFP. This is due to the inability of the knee to perform extensor torque, which increases pressure on the patellofemoral [12, 13, 29]. Conversely, from the perspective of ACL injury, research by Colby et al. [29] revealed that ACL injuries occur because the ischio rurales (musculus biceps femoris, musculus semitendinosus, and musculus semimembranosus) may be unable to adapt to or protect the ACL from stress caused by explosive movements. As a result, there may be an imbalance in the hip and a mismatch of muscle activation performance between the quadriceps femoris muscle and the ischio rurales, which increases the risk of ACL injuries [29].

Hamstring flexibility is correlated with LBP [9]. Salder et al. [9] concluded that reduced hamstrings lead to an LBP risk. This seems acceptable, considering the explanation, Salder et al. [9] revealed that when the hamstring experiences inflexibility, it may cause an imbalance in the hip, creating excessive stress on the trunk, and the risk of LBP increases. The findings in this study support the previous theory regarding the correlation between hamstring flexibility and knee injuries and hamstring flexibility with LBP [9-11]. Moreover, this study demonstrated that athletes with a history of knee injuries had less flexibility than those with no history of non-injuries. In this context, it can be understood and proven that reduced flexibility in athletes with a history of knee injuries increases the risk of hip imbalance; in the end, this indication is characterized by decreased TMS performance.

TMS is an indicator of the risk of LBP [11]. This was revealed by studies, which stated that the weakness of TMS is strongly implicated in LBP [11, 30]. Although we did not find a comparison with previous studies that correlated flexibility and TMS in badminton athletes with a history of knee injuries, it is understandable that athletes with a history of knee injuries should pay more attention to the risk of LBP injuries in the future. This is because, there is an inflexibility factor in the hamstring, which may cause hip imbalance in the hip [11, 30]. Since athletes with knee injuries are at more risk of low back pain (LBP) than those without knee injuries, we encourage badminton athletes, coaches, and sports practitioners to increase their attention to healing methods, choice of exercise methods, or other aspects of training in badminton so that the risk of LBP can be minimized.

Although this study has succeeded in revealing a correlation between hamstring flexibility in athletes affected by knee injuries and variable TMS, this study has limitations that cause some unanswered issues, such as: (1) the need for blood biomarkers, X-rays, or other medical examinations to further investigate the correlation between the hamstring flexibility athlete and the TMS variable; (2) future studies are expected to quantitatively determine the risk percentage of athletes with a history of knee injuries who will develop LBP in the future; and (3) future research is expected to be able to conduct a more in-depth analysis based on exercise factors, lifestyle, or nutritional patterns, which are likely to be influential in the results of this study.

5. Conclusions

This study shows that the AKPS and VAS have a positive correlation in describing the level of pain and function of the knee. Furthermore, this study showed that the AKPS had a negative correlation with flexibility and TMS performance. Therefore, this study concretely illustrates that a low level of hamstring flexibility in athletes with a history of knee injuries can increase the risk of developing LBP, with a marked decrease in the performance of the TMS athlete.

Practical Implication

This research encourages coaches and badminton athletes to pay more attention to the management of acute injuries, especially knee injuries, so that they do not cause chronic injuries in the future. Specifically, this study recommends four items for badminton athletes: (a) preventing overtraining, which can increase the risk of injury; (b) performing complete healing therapy and not carrying out training activities if the healing process is not perfect; (c) improving muscle strengthening and correction of movement patterns by performing strength training, balance training, and running/flexibility exercises; and (d) increasing information knowledge about injury mechanisms.

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