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ORIGINAL SCIENTIFIC ARTICLE

ASSOCIATION BETWEEN MEDIAL LONGITUDINAL ARCH WITH STATIC AND DYNAMIC BALANCE AMONG RECREATIONAL BADMINTON PLAYERS

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Abstract

The study purpose was to examine the association between the Medial Longitudinal Arch (MLA) and balance among recreational badminton players.

Materials and methods. Total of 48 recreational badminton players aged 18-40 (24 males and 24 females) were recruited. Navicular Drop Test (NDT), Single Leg Stance Balance Test (SLSBT) and Modified Star Excursion Balance Test (mSEBT) were assessed on both dominant and non-dominant leg. Participant's foot type was categorized using NDT scores according to difference of navicular height in weight bearing and relax sitting; static balance was grouped based on the time (seconds) the players were able to maintain balance during the SLSBT; and dynamic balance was grouped based on the percentage of distance reached in mSEBT.

Results. The study results revealed a significant association between the MLA of dominant ($p < 0.05$) and non-dominant leg ($p = 0.02$) with static balance among recreational badminton players. However, there is no significant association between the MLA of dominant (Anterior: $p = 0.39$; Posteromedial: $p = 0.34$; Posterolateral: $p = 0.98$) and non-dominant leg (Anterior: $p = 0.39$; Posteromedial: $p = 0.54$; Posterolateral: $p = 0.07$) with dynamic balance.

Conclusions. The current study concludes that there is a significant association between the MLA and static balance. However, no changes were seen in dynamic balance. Thus, coaches and trainers may look into the MLA of players to improve their static balance, which can further improve their sports performance. Future studies are recommended to examine the effects of dynamic balance in more depth with increased sample size.

Keywords: recreational badminton players, balance, medial longitudinal arch, dominant leg arch, non-dominant leg arch.

Introduction

Badminton as a contactless sport requires quick motion of the body where players have to lunges, jump and react to changes in position during the game (Marchena-Rodriguez et al., 2020). Badminton involves defending and shooting strategies which require many skills like net shot, jump smashes, overhead strokes, effective serving and defending (Paup & Fernhall, 2017). Besides having good skills to dominate the opponent, the ability to maintain their own static and dynamic balance is also very necessary for badminton players in order to have a better performance (Masu et al., 2014). Static balance refers to the ability to maintain a stable posture; whereas dynamic balance is our ability in respond to various alteration of our body position (Tsigilis, 2001). In terms of motor and movement functions, coordinating variables such as static and dynamic balances; foot anatomy and movement; and response time plays a significant role in the badminton sports (Hamed Ibrahim Hassan, 2017). In a previous study, amateur badminton players were found to have serving accuracy, but lack of static and dynamic balance (Wong et al., 2019). Moreover, as badminton is a unilateral sport, the dominant limb's motions are more accurate and faster than those of the non-dominant limb, predisposing

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players to acquire certain imbalances (Manolova, 2018). Asymmetry between the sides of the body can increase the chance of injury and negatively impact a player's effectiveness (Manolova, 2018).

The medial longitudinal arch (MLA) is one of the main factors that affect our balance while static standing and moving around (Salvastore & Nur Khairunisa Abu Talip, 2020). The MLA is supported by plantar ligaments, muscles, and tendons and consists of the tarsal (talus, calcaneus, navicular, and three cuneiform bones) and metatarsal bones of the big toe (Babu & Bordoni, 2021). MLA offers the plantarflexors sufficient mechanical advantage in raising our bodyweight during stance phase and assist in absorbing the increased shock during upright standing (Justine et al., 2016). Hence, our body posture may appear to be disturbed if the biomechanical changes in this supporting structure are disrupted and our foot quality will be dramatically impaired by its design (Hashimoto et al., 2010; Justine et al., 2016).

A causal link between arch formation and musculoskeletal injury trends is indicated as low arch foot due to the changes of head of talus position from the navicular causes the MLA to drop and lengthen the tendon as well as the surroundings ligaments (Justine et al., 2016). As a result, if the neuromuscular system could not meet the demands of maintaining postural balance, musculoskeletal injury would possibly occur (Justine et al., 2016). On the other hand, the high arch foot with a rigid lever is less efficient to work as a shock absorber (Justine et al., 2016). When sustaining postural balance, the high arch foot was unable to equally carry the body weight, shifting the centre of pressure laterally and as a result, people with high arches acquire pain and foot injuries frequently (Justine et al., 2016). Furthermore, both high and low foot arch have been linked to an increased risk of lower limb injuries, and have been recognized as prone to the occurrence of stress fractures in the foot and lower leg (Hollander et al., 2019; Justine et al., 2016).

Due to the nature of badminton sports, the majority of badminton players suffer ankle injuries as a result of instability while landing (Herbaut et al., 2018). Recent studies conducted on the effects of MLA on static and dynamic balance has been conducted only among female healthy athletes (Salvastore & Nur Khairunisa Abu Talip, 2020) and male collegiate athletes involving sports such as volleyball, basketball, handball (Hasan et al., 2017). There is a paucity of research that have been conducted on MLA and balance among badminton players owing to the nature of the sports of quick and strong jump smashes and very swift reflex exchanges.

Thus, the current study aimed to examine the association between MLA and balance (static and dynamic balance) among the recreational badminton players. We hypothesize that the different heights of MLA (low and high arch) affect the static and dynamic balance of the badminton players.

Materials and methods

Study participants

The current study recruited 48 recreational badminton players (24 males and 24 females) (Age: 24.17 ± 4.07). The following inclusion and exclusion criteria were used to recruit participants. Participants in this study ranged in age from 18 to 40 years old, played badminton at least once a week, and did not compete in any badminton tournaments or any other sports. Participants were excluded from the study if they reported any health issues, any pre-existing lower limb injury, or if they had previously participated in physical training. Prior to participation in the study, all individuals were informed about the testing procedures and completed a written consent form. The study was approved by the Research and Ethics Committee from INTI International University (approval no. INTI-IU/FHLS-RC/BPHTI/7NY12020/006)

Study organization

This was a quantitative experimental study to determine the association between the MLA and balance. The test was completed in a single session. Prior to the physical examination, participants were given a consent form and PARQ+ 2021 to complete. After the introduction and briefing, the participants performed the Navicular Drop Test (NDT), Single Leg Stance Balance Test (SLSBT) and Modified Star Excursion Balance Test (mSEBT).

Medial Longitudinal Arch (MLA) assessment. The MLA of the participants was measured based on the following procedure below:

1. The dominant leg of a participant was determined by asking them which leg they jump and lift off the ground when completing a jump smash (Hamed Ibrahim Hassan, 2017).
2. The participants were then instructed to relax and sit on the bench/chair with their bare feet on the ground.
3. A marker pen was used to palpate and label the prominent navicular tuberosity. A ruler was placed next to the navicular tuberosity on the medial part of the foot. The distance between the prominent navicular tuberosity and the floor was measured in millimetre (mm) s to determine the height of the navicular tuberosity.
4. The subject was then instructed to stand up on one leg, completely weight bearing on the assessed foot only.
5. The assessor palpated the talar dome with his thumb (positioned antero-inferior to the medial malleolus) and index finger (placed at antero-inferior of fibula). The height of the navicular tuberosity was measured once more by measuring the distance in millimetres (mm) between the prominent navicular tuberosity and the floor.
6. The distance between the prominent navicular tuberosity and the floor was measured during relaxed sitting and single-leg weight bearing. The same steps were taken for both the dominant and non-dominant limb. Each side is measured three times, and the average height difference is calculated.
7. Participants are divided into three groups based on the height of the navicular prominent from the floor during weight bearing and relaxed sitting: high arch (navicular drop less than or equal to 4 mm), normal arch (navicular drop between 5 mm - 9 mm), and low arch (navicular drop more or equal to 10 mm) (Cote et al., 2005; Langley et al., 2016).

Static Balance: Single Leg Stance Balance Test (SLSB). The participants' static balance was evaluated using the following procedure (ATEŞ, 2017; Tsai et al., 2006):

1. SLSBT was performed with participants standing barefoot on an even floor with both feet. Students were requested to begin the SLSBT with either their dominant or non-dominant leg at random.
2. During the assessment, participants performed with eyes closing, both hands crossed in front their chest and the tested leg straighten while the non-tested leg was bent 90º in the air. They will need to maintain in the single leg standing position motionless as long as possible.
3. A digital stopwatch was used to time the duration (seconds) of the three Single Leg Standing test trials. When any of the following errors happened, time was halted:
   - The non-tested foot touched the floor or the tested leg.
   - Participant's tested foot off the testing surface.
   - Participant's hand left its position from their chest.
   - Participant opened their eyes.
   - Participants able to maintain and stand in position for more than 50 seconds.
4. The same steps were performed on both the dominant and non-dominant leg. The time for SLSBT was measured three times for both the dominant and non-dominant leg, and the average was calculated.
5. For each leg, the average time that the participant should sustain the necessary single-leg stance on the floor surface was calculated and was rated on a scale of 1 (poor), 2 (fair), 3 (average), 4 (good) and 5 (excellent).
6. The SLSBT scoring for the age range 18-40 years old was classified as follows:

Scoring	Age groups	
	18-29 years	30-40 years
50 + seconds	Excellent	Excellent
40-50 seconds	Good	Good
25-39 seconds	Average	Good
10-24 seconds	Fair	Fair
5-9 seconds	Poor	Poor

(ATEŞ, 2017; Emery, 2003; Tsai et al., 2006)

Dynamic Balance: modified Star Excursion Balance Test (mSEBT).The modified SEBT involves the uses of three tapes connecting to each other from the anterior, posteromedial and posterolateral direction. The following is the method used for measuring dynamic balance among the participants:

1. Participants were instructed to start the test by randomly putting their heel of either dominant or non-dominant leg at the intersection 'X' of the inverted 'Y'.
2. Participants were required to extend as far as they could towards the three directions of anterior (ANT), postero-medial (PM), and postero-lateral (PL) using the tips of their free leg's big toes without losing their balance with hands on the waist. Trials were halted if any of the participants committed one of the following errors:
   - Their foot off the intersection of the inverted 'Y'.
   - Participants unable to maintain balance.
   - The free leg touches ground when reaching to ANT, PM or PL.
   - Hands off from their iliac.
3. The participants were then instructed to repeat the three directions three times before switching legs.
4. The reach out distances was measured in centimetres (cm) and the average was calculated for both dominant and non-dominant leg.
5. Following the test, the participant's true limb length in supine position was assessed. The measurement started at their anterior superior iliac spine (ASIS) and ended at the distal end of their medial malleolus, with both feet 20 cm apart. The measurement was done in centimetres (cm).
6. The test results were then determined by taking the average of the reaching out distance and standardising it on the limb length.
7. To eliminate inaccuracy due to limb length disparities, a formula of (average reaching value/limb length) × 100 was employed. As a result, the normalised data were calculated as percentages of the excursion distance and their relationship to limb length. (ATEŞ, 2017; Bulow et al., 2019; Hamed Ibrahim Hassan, 2017; Hyong & Kang, 2016).

Statistical analysis

The data were analyzed using IBM SPSS Statistics version 28.0. The Shapiro-Wilk normality test was used, and all of the data were found to be normally distributed. To present the values of each variable, descriptive analysis was used to compute the mean, standard deviation, frequencies, and percentages. The chi-square was used to examine the association between the arch group and recreational badminton players' static and dynamic balance. In all analyses, the significance level was set at 0.05 with a 95% confidence level.

Results

In the current study, forty-eight participants were recruited. The baseline demographics details of the participants were presented in Table 1.

Table 1. Demographic characteristics of the participants

Demographic variables	Subcategory	Mean ± SD	Frequency (%) (N = 48)
Gender	Male		24 (50)
	Female		24 (50)
Age (year)		24.17 ± 4.07	
	18-25		37 (77.1)
	26-30		4 (8.3)
	31-35		7 (14.6)
BMI (kg/m^2)		21.42 ± 3.99	
	Under weight		14 (29.2)
	Normal weight		23 (47.9)
	Over weight		9 (18.8)
	Obesity		2 (4.2)

SD – standard deviation

In dominant leg, the mean ± SD of the MLA was 6.79 ± 3.33 mm. Majority of them are categorized in the normal arch group. Whereas, in non-dominant leg, the mean ± SD of the MLA was 7.00 ± 3.51 mm as mentioned in Table 2.

Table 2. MLA among recreational badminton players.

Type of arch	Dominant Leg (N = 48)		Non-Dominant Leg (N = 48)	
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD
Low arch	15 (31.3)		17 (35.4)	
Normal arch	18 (37.5)	6.79 ± 3.33	15 (31.3)	7.00 ± 3.51
High arch	15 (31.3)		16 (33.3)	

In dominant and non-dominant leg, majority of the participant's static balance was 'Fair' in table 3 that represents the static balance of the recreational badminton players. Majority of the participants score 'Excellent' in both dominant leg and non-dominant leg when reaching out towards the three directions (ANT, PM and PL) in the modified SEBT as in Table 3.

There is a significant association between dominant leg ($p < 0.05$) and non-dominant leg ($p < 0.05$) MLA and static balance as in Table 4.

There is no significant association between medial arch of dominant leg (ANT: p = 0.39; PM: p = 0.34; and PL: p = 0.98) and non-dominant leg (ANT: p = 0.39; PM: p = 0.54; PL: p = 0.07) with dynamic balance as in Table 5.

Table 3. Static and dynamic balance among recreational badminton players.

Balance	Dominant Leg (N = 48)		Non Dominant Leg (N = 48)	
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD
Static balance		19.19 ± 10.31		18.96 ± 12.66
Poor	10 (20.8)		14 (29.2)	
Fair	25 (52.1)		22 (45.8)	
Average	11 (22.9)		8 (16.7)	
Good	1 (2.1)		2 (4.2)	
Excellent	1 (2.1)		2 (4.2)	
Dynamic balance				
ANT		94.37 ± 0.12		92.79 ±13.21
Poor	7 (14.6%)		7 (14.6%)	
Excellent	41 (85.4%)		41 (85.4%)	
PM		90.33 ± 10.72		87.92 ± 10.37
Poor	5 (10.4%)		11 (22.9%)	
Excellent	43 (89.6%)		37 (77.1%)	
PL		88.78 ± 11.35		86.93 ± 12.53
Poor	10 (20.8%)		13 (27.1%)	
Excellent	38 (79.2%)		35 (72.9%)	

SD – standard deviation; ANT – Anterior; PM – Posteromedial; PL – Posterolateral

Discussion

The current study aimed to examine the association between medial longitudinal arch with static and dynamic balance among recreational badminton players. The findings of the current study support our hypothesis that the static balance of badminton players with low and high MLA has been affected. However, no association has been found between the height of MLA and dynamic balance. Thus, the hypothesis that stated the influence of low and high MLA on dynamic balance has been rejected.

Table 4. Association between MLA and static balance among recreational badminton players

Static Balance	Dominant Leg				Non Dominant Leg			
	Frequencies (n)				Frequencies (n)			
	Low arch	Normal arch	High arch	P value	Low arch	Normal arch	High arch	P value
Poor	3	0	7		6	1	7	
Fair	10	10	5		8	5	9	
Average	2	6	3	<0.05	3	5	0	<0.05
Good	0	1	0		0	2	0	
Excellent	0	1	0		0	2	0	
Total	15	18	15		17	15	16	

Table 5. Association between MLA and dynamic balance among recreational badminton players

Dynamic balance		Dominant Leg				Non-Dominant Leg			
		Frequencies (n)			P value	Frequencies (n)			P value
		Low arch	Normal arch	High arch		Low arch	Normal arch	High arch	
ANT	Poor	3	1	3	0.39	4	1	2	0.39
	Excellent	12	17	12		13	14	14	
PM	Poor	1	1	3	0.34	5	2	4	0.54
	Excellent	14	17	12		12	13	12	
PL	Poor	3	4	3	0.98	5	1	7	0.07
	Excellent	12	14	12		12	14	9	

The MLA of the dominant and non-dominant legs was found to be significantly associated with static balance in recreational badminton players. Static balance issues were more common in participants with low and high arches than in those with normal arches, with the majority falling into the "Poor" or "Fair" category. When standing statically on the ground, the smaller plantar contact area reduces sensory afferent input, which may explain why participants with high arches had more difficulty maintaining static balance than those with normal arches (Hertel et al., 2002; Tsai et al., 2006). The sensory afferent input in the plantar surface is crucial as it enhances the postural control (Hertel et al., 2002). Besides, the proprioceptive feedback during ankle movement comprises divergent information from skin, articular, and muscular mechanoreceptors in addition to sensory information from joint receptors (ligament and capsule) (Cote et al., 2005; Riemann & Lephart, 2002). Reduction of surface area between plantar region and contact surface results in lack of sensory information to be sent to the central nervous system (Hasan et al., 2017). Hence, when there are changes in postural instability during standing (displacement of compression centre of pressure), the static balance decrease respectively (Hasan et al., 2017). The findings of this study are consistent with other previous studies stating the individuals with high arch will have less effective methods to maintain an upright posture during single leg standing balance (Cote et al., 2005; Hertel et al., 2002; Tsai et al., 2006).

The current study also showed that participants in the low arch group presented with greater difficulties in maintaining static balance when comparing with the normal arch group. Despite the fact that the lower arch foot has a larger surface area in contact with the surface, which allows more information to reach the skin, deep, subcutaneous, and articular sensory receptors, resulting in better static balance, the low arch group still has poorer static balance than the normal arch group. This might be due to the difference of foot structure and biomechanics (physiologic limitation of the range of motion of subtalar and midtarsal joint) (Hasan et al., 2017; Hertel et al., 2002).

The findings from this study demonstrated the dynamic balance of recreational badminton players was not affected by the MLA in both dominant and non-dominant leg. Majority of the participants in all arch groups had 'Excellent' (>0.80) in the three directions reaching (ANT, PM, and PL), Modified SEBT test. The nature of badminton, especially during lunges and quick reactive movement encompassing the entire court, may explain why majority of the players were able to score 'Excellent' on this exam (Desai & Gandhi, 2020). The findings of the current study correspond to other studies in which the dynamic balance of the dominant and non-dominant legs was not affected by the types of MLA (Hasan et al., 2017; Hyong & Kang, 2016; Justine et al., 2016; Kim et al., 2015). The investigations indicated a lack of association between the arch and dynamic balance as a result of foot muscles such as the peroneus longus and tibialis anterior compensating for postural adaptation (Hyong & Kang, 2016; Kim et al., 2015).

However, past research has suggested that in people with a low arch, the medial side of the foot drops, reducing the lateral and posterolateral reaching distance (Cote et al., 2005). The collapsed medial part of foot has an impact on the length-tension relationship of the foot intrinsic muscles as the prolong lengthen of muscles and soft tissues causes the low arch foot to fatigue easily compare to other foot type (Kulkarni & Thosar, 2020; Chen et al., 2016; Justine et al., 2016). Contrarily, reduction of ankle dorsiflexion and the shortening of gastrocnemius in high arch foot also negatively affects the performance when maintaining dynamic stability (Justine et al., 2016). Therefore, foot posture modifications may lead to additional changes in musculoskeletal characteristics and joint flexibility, increasing the risk of accidents and falls (Justine et al., 2016; Kulkarni & Thosar, 2020).

The main limitation of the current study is the participants with asymmetrical of foot were not excluded from the study. Other than that, confounding variables like lower limb rotational deformities such as Q-angle and tibia torsion were not included in the current study.

Conclusions

This study had shown that there is a significant association between the MLA of dominant and non-dominant leg with static balance among recreational badminton players. However, there is no significant association between dominant and non-dominant leg MLA and dynamic balance in anterior, posteromedial and posterolateral reaching. Recreational badminton players should enhance their ability to maintain postural balance so that they can move in a stable stance and react quickly to incoming shuttlecocks in order to avoid injury. Future studies may be conducted with a larger sample size among the elite badminton players for further understanding.

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Conflict of interest

The author(s) declare(s) that there is no conflict of interest.

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ЗВ'ЯЗОК МІЖ МЕДІАЛЬНИМ ПОЗДОВЖНІМ СКЛЕПІННЯМ СТОПИ ТА СТАТИЧНОЮ ТА ДИНАМІЧНОЮ РІВНОВАГОЮ В БАДМІНТОНІСТІВ-ЛЮБИТЕЛІВ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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Метою дослідження було вивчення зв'язку між медіальним поздовжнім склепінням стопи (МПСС) та рівновагою в бадмінтоністів-любителів.

Матеріали та методи. У досліджені брали участь загалом 48 бадмінтоністів-любителів віком від 18 до 40 років (24 чоловіки та 24 жінки). На домінантній і на недомінантній нозі було проведено тест на опущення човноподібної кістки стопи (NDT), тест на збереження статичної рівноваги стоячи на одній нозі (SLSBT) та модифікований тест на збереження динамічної рівноваги стоячи на одній нозі та рухаючи другою, намагаючись дістати нею якомога далі у восьми напрямках подвійного перехрестя у формі «зірочки» на підлозі (mSEBT), і виконано оцінку результатів тестування. Було проведено класифікацію типу стопи кожного учасника з використанням оцінок у тесті NDT відповідно до різниці висоти човноподібної кістки стопи в стані вагового навантаження на ногу та в стані розслабленого сидіння; показники статичної рівноваги класифікували за часом (у секундах), протягом якого гравці були здатні зберігати рівновагу під час виконання тесту SLSBT; показники динамічної рівноваги класифікували за відсотковою часткою відстані, досягнутої під час виконання тесту mSEBT.

Результати. За результатами дослідження в бадмінтоністів-любителів виявлено суттєвий зв'язок між МПСС домінантної ($p < 0,05$) і недомінантної ($p = 0,02$) ноги та статичною рівновагою. Проте суттєвого зв'язку між МПСС домінантної (передня частина: $p = 0,39$; задньомедіальна частина: $p = 0,34$; задньолатеральна частина: $p = 0,98$) і недомінантної (передня частина: $p = 0,39$; задньомедіальна частина: $p = 0,54$; задньолатеральна частина: $p = 0,07$) ноги та динамічною рівновагою не виявлено.

Висновки. На підставі результатів цього дослідження зроблено висновок про наявність суттєвого зв'язку між МПСС та статичною рівновагою. Проте жодних змін стосовно динамічної рівноваги не спостерігалося. Таким чином, тренери та інструктори можуть вивчати МПСС гравців із метою покращення їхньої статичної рівноваги, що може додатково покращити їхні спортивні показники. Рекомендується проведення подальших досліджень для більш поглибленого вивчення властивостей динамічної рівноваги зі збільшеним обсягом вибірки.

Ключові слова: бадмінтоністи-любителі, рівновага, медіальне поздовжнє склепіння стопи, склепіння стопи домінантної ноги, склепіння стопи недомінантної ноги.

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