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The relationship between fear of movement and ankle biomechanical strategies in a 180° change of direction task

Samuel P. Brogan [a], David W. Evans [b], Louis Howe [a], Christopher McManus [a], Qichang Mei [c,d], Bernard X.W. Liew [a,*]

[a] School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, Essex, United Kingdom
[b] School of Sport, Exercise and Rehabilitation Sciences, College of Life and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom
[c] Faculty of Sports Science, Ningbo University, Ningbo, China
[d] Auckland Bioengineering Institute, The University of Auckland, Auckland, New Zealand

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ABSTRACT

Objective: To assess the association between fear of movement and ankle biomechanics and timed performance in a 505 agility change of direction (COD) test, and to assess the association between the biomechanical indices with timed performance.

Methods: Twenty participants, who play football at a university level or higher, with a history of ankle injuries were recruited. All participants performed three maximal effort 505 agility COD tests. Three-dimensional ankle range of motion (ROM, measured using inertial measurement units) and the average ankle muscle co-activation (tibialis anterior, soleus, and peroneus longus muscles of the affected limb, measured using bipolar surface electromyography) were extracted from the stance phase of the final cutting step. Fear of movement was assessed using the Tampa Scale of Kinesiophobia 11-item (TSK-11) questionnaire.

Results: TSK-11 significantly correlated with ankle transverse plane ROM: $r = -0.53$ (95 %CI −0.79 to −0.11), $t = -2.63$, $P = 0.017$. There was no significant association between the COD timed performance and the four ankle biomechanical indices.

Conclusions: Greater fear of movement may result in a stiffer turning strategy, which may reduce the risk of injury to the ankle. However, fear of movement is less likely to moderate ankle kinematic and muscle activation strategies that give rise to a performance-injury conflict.

1. Introduction

Football (soccer) is recognized as the most popular sport in the world [1]. The demands that influence performance are both physical [2] and technical [3], requiring players to perform between 700 and 1400 changes of direction (COD) per game [4]. In football, COD movements include turns of varying degrees, enabling a player to transition from attack to defense (and vice-versa) and to create space from an opponent [5]. The assessment of 180° COD performance is conducted via tests such as the 505 agility test [6]. A 180° COD involves (1) braking to slow the body down, (2) rotating the body in the new direction of travel, and (3) propelling to accelerate the body toward top-speed running [7].

Biomechanical strategies that optimize COD performances may also increase the risk of injuries, thereby creating a performance-injury conflict [7]. Faster COD times have been associated with several biomechanical strategies, specifically: lower knee and ankle muscle coactivation [8]; reduced hip and knee flexion range of motion (ROM) [7]; a reduced knee flexion angle [7]; a greater knee extensor moment [7]; a greater ankle plantar flexor moment [9]; a more internally rotated foot progression angle [7]; and a greater ankle inversion angle [10] during the stance phase. However, several of these biomechanical strategies have also been shown to increase the risk of musculoskeletal injuries. For example, a reduced knee flexion angle during landing may increase the risk of anterior cruciate ligament (ACL) tear [11], while a greater ankle inversion angle may increase the risk of a lateral ankle sprain (LAS) [12].

The COD biomechanical performance-injury conflict has been investigated with a focus on knee biomechanics and the risk of ACL injury [7]. However, ankle biomechanics have not been vigorously investigated from the perspective of the performance-injury conflict.

* Corresponding author.
E-mail addresses: bl19622@essex.ac.uk, liew_xwb@hotmail.com (B.X.W. Liew).

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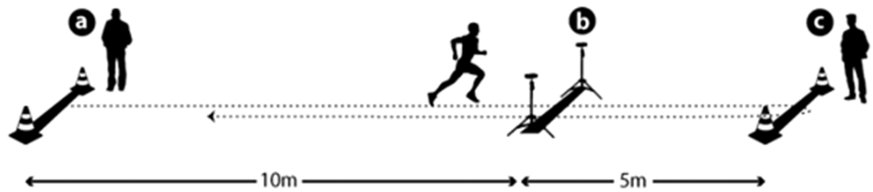

Fig. 1. 505 Agility Test Diagram.

This is surprising given that ankle biomechanics can influence COD performance [8], and COD activities are a common mechanism of ankle injuries in sports [13]. Additionally, following an ankle injury, ankle biomechanics during dynamic sporting maneuvres are associated with the successful return to sport without persistent symptoms (i.e., 'copers') [14]. For example, individuals with persistent ankle symptoms of instability exhibit greater frontal plane displacement, and increased ankle inversion angle during various types of jump-landings [14]. Alterations to ankle biomechanical strategies may also be accompanied by alterations to the proximal knee and hip joint biomechanics, which may either be compensatory [15] or synergistic [16]. This suggests that 'coper' athletes may adopt protective biomechanical strategies during dynamic sporting maneuvers that reduce the risk of an injury recurrence. However, whether these protective strategies negatively impact COD performance has yet to be investigated.

Contemporary models of pain [17,18] have proposed a link between fear of movement and movement biomechanics [19–24]. In people with low back pain (LBP), those with a greater fear of movement exhibit greater trunk stiffness [19]. Furthermore, people with a greater fear after an ACL reconstruction demonstrate a greater level of knee muscle co-activation during a drop-landing task than those with lower levels of fear [21]. Trigsted et al. [23] reported greater fear associated with reduced knee, hip, and trunk flexion angles during a jump-landing task, indicative of a stiffer movement strategy. To the authors' knowledge, no studies have investigated the influence of fear of movement on ankle biomechanics in a COD task.

The primary aim of this study was to assess the association between fear of movement and ankle biomechanics and timed performance in a 180° ankle COD task. We hypothesized that greater fear of movement would be associated with higher ankle muscle co-activation (H1), reduced three-dimensional ankle joint range of motion (ROM) (H2), and diminished COD timed performance (H3). The secondary aim of this study was to assess the association between the kinematic and muscle indices with time to perform a maximal effort COD test. Here, we hypothesized that quicker COD completion times would be associated with reduced ankle muscle co-activation (H4) and greater ankle ROM magnitudes in all three planes of motion (H5). Lastly, we explored whether fear of movement and performance time were significantly associated with knee and hip ROM.

2. Methods

2.1. Study design

Cross-sectional laboratory investigation.

2.2. Participants

Ethical approval was gained from the University of Essex Research Ethics Committee (ETH2324–0470). Participants were eligible to take part if they fulfilled the following criteria: (1) aged 18–30 years; (2) absence of any medical condition that precludes participation in strenuous exercise, as self-reported; (3) no prior history of lower limb surgery; (4) participated in football at university team level or higher at least once a week; and (5) had suffered an ankle injury during football over the last 12 months.

2.3. Sample size

A previous study reported a moderate association between fear of movement and the magnitude of muscle activation [23]. Based on a moderate correlation of 0.6, a power of 0.8, and an alpha of 0.05, it was estimated that 18 participants would be required. In case of data corruption or participant dropouts, we recruited 20 participants.

2.4. Participant reported measures

Injury history, present level of football participation, and current physical activity levels were collected to describe participant characteristics. Fear of movement was assessed using the 11-item Tampa Scale of Kinesiophobia (TSK-11) questionnaire. The TSK-11 has demonstrated good internal consistency [25,26]. A previous study grouped the TSK-11 scores into four categories: minimal fear (score $\leq$ 22), low fear (score of 23–28), moderate fear (score of 29–35), and high fear (score $\geq$ 36) [27].

2.5. COD performance

The 505 agility test was completed on a standard indoor floor surface (Fig. 1). Participants were instructed to start 0.5 m behind the start line (point 'a'). On the investigator's command, the participant sprinted 15 m forwards 'as fast as possible' through a set of time gates located 10 m in front of the start line (point 'b'). At the 15 m line (point 'c'), the participant performed a 180° COD before reaccelerating through the finish line (point 'b'). Participants were required to turn using their affected leg. Each participant was asked to complete the test 3 times, each separated by a 5-minute rest period. The average time taken to complete the test was calculated and used for subsequent analyses.

2.6. Instrumentation and processing

Three wireless bipolar surface electromyography (sEMG) sensors (Noraxon Ultium™, USA, 4000 Hz) were placed over the tibialis anterior, soleus, and peroneus longus muscles of the affected limb, following SENIAM guidelines. The peroneus longus and tibialis anterior were measured because of their role in ankle eversion and inversion, respectively. The soleus was measured because of its role in COD tasks for braking and propulsion, and also because it inverts the ankle [28].

Maximal isometric voluntary contraction (MVC) tests were conducted for amplitude normalization [29,30]. For the soleus, participants were seated with their hip and knees visually positioned at 90° and the ankle in a neutral posture. The assessor (SB) applied a downward force on the thigh proximal to the knee, whilst the participants were asked to raise the heel against the resistant force as hard as possible. For the tibialis anterior, the participants lay supine on the plinth, with their hip and knee visually positioned to 110° and the ankle in neutral posture. Participants were instructed to maximally dorsiflex the ankle against a manual plantarflexion resistance applied to the dorsum of the metatarsal region. For the peroneus longus, the participants lay supine on the plinth, with their hip and knee extended and the ankle in neutral posture. Participants were instructed to maximally evert the ankle against a manual inversion resistance applied by the assessor to the lateral region of the foot at the metatarsal region. Subsequent sEMG signals were amplitude normalized and expressed as a percentage of the

Table 1
Participant characteristics.

Variables	n (%) or mean ± standard deviation
Sex	
Male	10 (50)
Female	10 (50)
Age (years)	20.3 ± 2.1
Stature (meters)	1.7 ± 0.2
Mass (kg)	71.7 ± 11.2
Dominant side (leg to kick a ball)	17
Right	3
Left	
Number of football training sessions per	2 (10)
week	11 (55)
One	4 (20),
Two	1 (5)
Three	2(10
Four	
Five	
Location of Injury('s)	1 (5)
Foot/toe	20 (100)
Ankle	3 (15)
Lower leg/Achilles	4 (20)
Knee	3 (15)
Thigh	3 (15)
Hip/Groin	
Side of injury in the last 12 months	9 (45)
Left	10 (50)
Right	1 (5)
Both	
Cause of injury in the last 12 months	9 (45)
Overuse	11 (55)
Trauma	
Mechanism of injury in the last 12 months	10 (50)
Contact	10 (50)
Non-contact	
Severity of injury in the last 12 months	1 (5)
Minimal	6 (30),
Mild	7 (35)
Moderate	6 (30)
Severe	
Type of training participation in the last 7	17 (85)
days	1 (5)
Full	1 (5)
Full with discomfort	1 (5)
Reduced	
No participation through choice	
Tested side	13
Dominant limb	7
Non-dominant limb	

maximal values from the MVC trials. Seven inertial measurement unit (IMU) sensors (Noraxon Ultium™, USA, 400 Hz) were placed on the participant's pelvis and bilateral thighs, shanks (lower legs), and feet, according to the manufacturer's guidelines. Both sEMG and IMU signals were acquired simultaneously (vMR3 3.20.10, Noraxon, USA) software.

The sEMG signals were high pass filtered using a 2nd order IIR Butterworth, bidirectional, filter at 50 Hz, full-wave rectified, low pass filtered using a 2nd order IIR Butterworth, bidirectional, filter at 20 Hz, and amplitude normalized. IMU signals were low pass filtered using a bidirectional IIR Butterworth filter at 8 Hz. Gait events of initial contact and toe-off of the final step at point 'c' were manually identified. For ankle kinematics, the ROM in the sagittal, frontal, and transverse planes between gait events was extracted by calculating the difference between maximum and minimum values. ROM was selected as a metric for analysis because of the associations between fear and ROM in other anatomical regions [20,23], and joint stiffness [19] is related to joint ROM. The time-varying global muscle coactivation index between the gait events was determined based on the methods of a prior study [31]. The average muscle coactivation value across the gait events was calculated.

Table 2
Descriptive statistics of dependent variables.

Dependent Variable	Mean ± SD
TSK−11 (11 minimum to 44 maximum fear)	26.5 ± 5.9
505 timed performance (s)	2.64 ± 0.26
Frontal plane ankle range of motion (°)	18.30 ± 5.89
Sagittal plane ankle range of motion (°)	42.43 ± 8.59
Transverse plane ankle range of motion (°)	17.24 ± 7.84
Peak tibialis anterior activity (%)	226.78 ± 172.42
Peak peroneus longus activity (%)	196.89 ± 133.76
Peak soleus activity (%)	293.29 ± 270.07
Mean muscle co-activation index (%)	54.93 ± 15.94

2.7. Statistical analysis

All analyses were undertaken using R software (version 4.3.0). Pearson correlation coefficient, r, was calculated to assess the bivariate association between TSK-11 and the biomechanical variables (three ankle kinematics, one ankle co-activation, and one COD timed performance). Correlations between the timed performance and the four ankle biomechanical indices were also calculated. The strength of correlation was categorized as [32]: negligible ($|r| \leq 0.30$), low ($|r| = 0.31–0.50$), moderate ($|r| = 0.51–0.70$), high ($|r| = 0.71–0.90$), and very high ($|r| = 0.91–1$). To determine if the results could be confounded by the dominance of the tested leg, we performed a linear regression analysis with dominance as the predictor against the five dependent variables mentioned. As an exploratory analysis, correlations between TSK-11 and performance time on knee and hip ROM were also calculated. Alpha was set at 0.05.

3. Results

Twenty participants (10 male, 10 female) took part in the study. The demographic characteristics of these participants can be found in Table 1. The levels of fear on the TSK-11, the completion time on the 505 agility test, as well as the 3D ankle kinematics and muscular activities, are reported in Table 2.

The TSK-11 was significantly correlated with ankle transverse plane ROM: $r = -0.53$ (95 %CI −0.79 to −0.11). (Fig. 2). TSK-11 was not significantly associated with 505 agility test completion time ($r = 0.22$ [95 % −0.25–0.60]), ankle sagittal plane ROM ($r = 0.12$ [-0.34–0.54]), ankle frontal plane ROM ($r = -0.17$ [95 %CI −0.57–0.30]), and muscle co-activation ($r = -0.17$ [95 %CI −0.57–0.30]) (Fig. 2). Similarly, TSK-11 was not significantly associated with knee or hip ROM (Fig. 3).

A quicker timed 505 agility test performance was not significantly associated with ankle sagittal plane ROM ($r = -0.06$ [95 %CI −0.49, 0.39], $P = 0.800$), ankle frontal plane ROM ($r = -0.16$ [95 %CI −0.56, 0.31], $P = 0.504$), ankle transverse plane ROM ($r = -0.26$ [95 %CI −0.63, 0.20], $P = 0.264$), and ankle co-activation ($r = 0.26$ [95 %CI −0.21, 0.63], $P = 0.274$). There were also no significant associations between performance time and knee and hip ROM (Fig. 3). There was no significant effect of tested limb dominance on completion time ($t = 0.074$, $P = 0.942$), ankle sagittal ROM ($t = 0.553$, $P = 0.587$), ankle frontal plane ROM ($t = -0.10$, $P = 0.922$), ankle transverse plane ROM ($t = -0.862$, $P = 0.400$), and muscle coactivation ($t = -1.471$, $P = 0.159$).

4. Discussion

Fear of movement has been considered to be a prominent psychological factor that influences return to sport rates after an injury [18]. In line with other studies reporting a greater fear of movement being associated with reduced sagittal plane ROM at the knee and trunk [20, 23], we found a statistically significant moderate negative relationship between fear of movement and ankle transverse plane ROM (supporting H2).

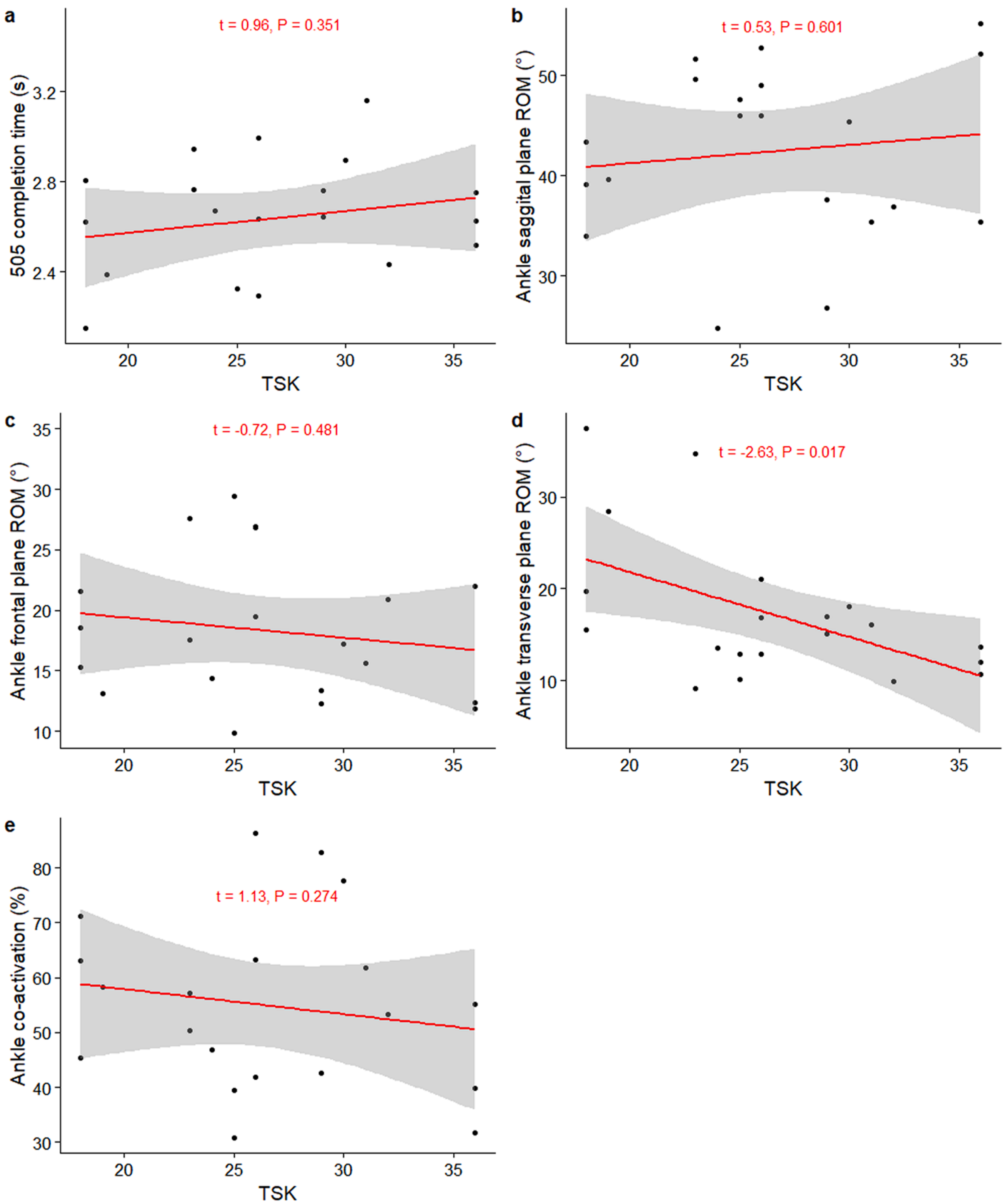

Fig. 2. Pearson correlation between TSK values and a) completion time of the 505 agility test, b) ankle sagittal plane ROM, c) ankle frontal plane ROM, d) ankle transverse plane ROM, and e) ankle muscle co-activation.

However, our results also contradicted those reported by others. Previous studies reported an association between greater fear of movement and higher knee muscle co-activation [21], increased gluteal maximum activity [23], and greater bicep femoris activity [21]. By contrast, we saw the fear of movement not to be associated with ankle muscle co-activity (not supporting H1), or performance time (not supporting H3). In addition, performance time was not associated with ankle muscle co-activity (not supporting H4) and ankle ROM (not supporting H5).

It is unlikely that the lack of association that we found between fear and the biomechanical indices could be attributed to low levels of fear since our cohort's mean TSK-11 score was similar to those reported in previous studies (ranging from 20.0 to 22.7) [22–24]. This difference between previous research and our study could be due to the different activities used (lifting and jumping versus our COD task), or that we measured biomechanical indices in a different anatomical region (knee, hip, and trunk versus the ankle), and the location, severity and/or duration of the clinical condition (ACL reconstruction and chronic LBP rather than a history of an ankle injury) [20,21,23,24]. A previous review reported that individuals with ankle instability relied more on a hip

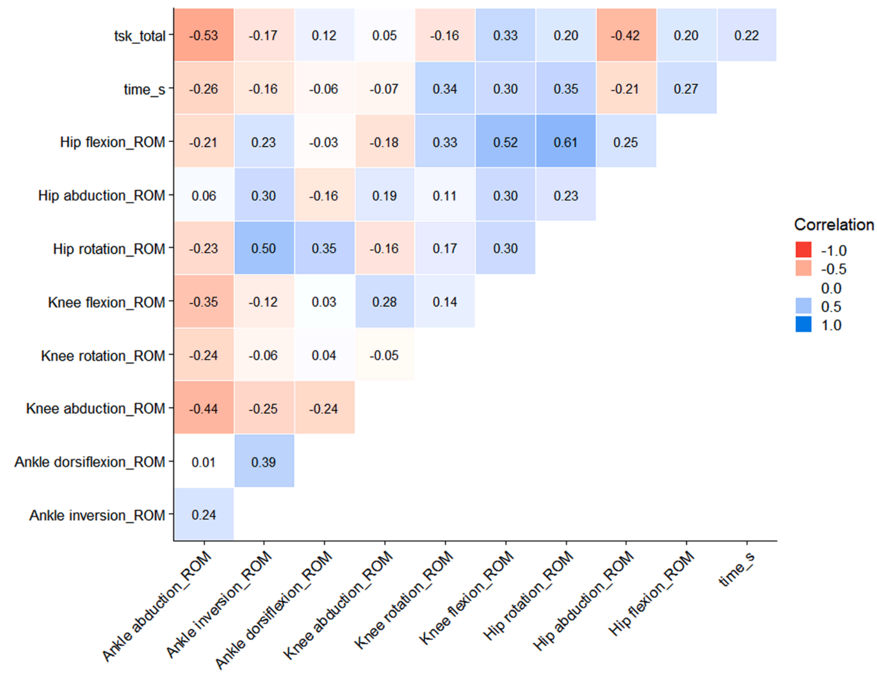

Fig. 3. Pearson correlation magnitudes between the TSK value, performance time, ankle, knee, and hip biomechanical variables.

strategy during various functional tasks, compared to those classed as "copers" [33]. Interestingly, we did not observe a positive association between hip and knee ROM against the fear of movement, which would suggest a compensatory biomechanical strategy was not adopted.

Interestingly, Markström [21], who assessed knee muscle co-activation of the ACL reconstructed limb, divided their participants into two sub-groups based on participants' responses to a single TSK-17 statement ("I am afraid that I might injure myself accidentally"). Their high fear group produced greater knee muscle co-activation strategies (low fear = 0.78, high fear = 1.06) compared to the low fear group during a single leg hopping task [21]. It may be that a more task-specific method of assessing fear may be better suited to understanding its association with alterations in the biomechanical strategies of movement. Indeed, a previous study showed that the aggregate TSK-11 score may underestimate task-specific fear in people with LBP [34]. Instead, incorporating images [34] of sporting maneuver may be better than a survey in providing a more task-specific thod of assessing movement-related fear.

The lack of association between fear of movement and ankle ROM in sagittal or frontal planes could be due to the specific demands imposed upon the ankle complex during the assessed task. In this investigation, the 505 agility test, which required a 180° COD, would place a greater demand on ankle transverse plane kinematics than a COD at a shallower angle. In contrast, a side-step cutting maneuver requiring a COD of < 90° may place a greater demand on ankle frontal plane kinematics [10]. Yu et al. [35] reported that individuals who cope after an ankle sprain performed a 45° side-step cut with a more everted and protective ankle posture, compared to individuals with chronic ankle instability. Other authors [36] have reported that individuals with chronic ankle instability landed with greater ankle inversion angle (i.e., more injury risk) than copers in an inversion-landing task. Furthermore, a systematic review reported that individuals with chronic ankle instability (i.e., non-copers) have greater levels of fear than copers and healthy controls [37]. These suggest that fear of movement may influence biomechanical strategies to a greater extent if it is a primary requirement for a sporting maneuver.

We found greater levels of fear of movement to be associated with the adoption of more protective biomechanical strategies [19,20,23]. Given that previous studies have reported greater levels of fear of movement in non-copers after an ankle sprain, there is ambiguity in whether greater fear results in more or less protective biomechanical strategies. One reason for this ambiguity could be that multiple psychological factors may increase the likelihood of coping after an injury, such as self-efficacy. For example, a previous study in LBP patients reported that individuals with lower levels of pain self-efficacy adopt more protective lumbar postural strategies than those with greater pain self-efficacy [38]. Further research is needed to clarify the interplay between fear of movement, self-efficacy, and the adoption of protective or coping biomechanical strategies following an ankle sprain.

4.1. Implications

The findings link self-reported fear of movement with a reduced ankle ROM, suggesting a stiffer ankle joint strategy. Our results support adopting a more holistic biopsychosocial framework for the rehabilitation and return-to-sport decision-making after an ankle sprain injury. This can be achieved by better assessment and management of fear during rehabilitation, and careful consideration of the potential confounding effects of fear of movement on ankle biomechanics in individuals with a history of an ankle sprain injury. The present findings also suggest that practitioners should consider the progressive prescription of activities that demand ankle ROM in the transverse plane to support athletes in exploring movement solutions that mitigate re-injury risk and develop movement degeneracy.

4.2. Limitations

First, COD was not performed on a grass surface where football training and matches occur. It is well established that different surfaces would result in distinct coordination strategies [39], which could influence the association between fear of movement and the kinematic performance of the task. Second, the present study did not investigate sex differences in the relationship between fear and biomechanical alterations. Previous studies have demonstrated sex differences in fear levels in individuals with musculoskeletal pain disorders synergy. Third, we did not include a healthy control group. This precluded understanding of the relationships between fear and the kinematic and EMG variables that differ between individuals with a history of an ankle sprain and a healthy cohort. Future research should investigate whether such differences exist in the association between fear and biomechanical alterations.

5. Conclusion

Greater fear of movement was associated with a reduced ankle transverse plane ROM, but not mobility in other ankle planes, muscle co-activation, and performance. This reflects that fear may result in a stiffer turning strategy, reducing the risk of ankle injury. Given that task performance was not associated with fear, fear of movement may be less likely to moderate the biomechanical strategies that give rise to a performance-injury conflict.

Ethical Approval

Ethical approval was gained from the University of Essex Research Ethics Committee (ETH2324–0470).

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CRediT authorship contribution statement

Liew Bernard Xian Wei: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mei Qichang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **McManus Christopher:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **Howe Louis:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **Evans David W:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Conceptualization. **Brogan Samuel P:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis.

Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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