THE INFLUENCE OF MOOD DURING TREADMILL RUNNING ON BIOMECHANICAL ASYMMETRY OF THE LOWER-LIMBS

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This study aimed to investigate if mood effects lower-limb biomechanical asymmetry during running. Twenty runners (13M, 7F; age 22-58 years), performed four 3-minute runs at their 5km pace (3.3 ± 0.3 m/s), preceded by a mood questionnaire. Baseline data were captured, followed by randomised mood conditions: anger, happiness, and sadness; elicited with film clips and music. Symmetry angles used for analysis. In the sadness condition, compared with baseline, biomechanical asymmetry significantly increased ($p < .05$) by 3.7% at ground contact for hip abduction, and at toe-off for knee abduction by 0.6% and internal rotation by 1.1%. Toe-off plantarflexion asymmetry decreased by 2.2% with anger, compared to baseline. Happiness did not appear to affect asymmetry. Results suggest sadness may increase asymmetry and associated overuse injury risk, and anger may facilitate symmetry.

KEYWORDS: symmetry, injury prevention, emotions, gait, kinematic, embodiment

INTRODUCTION: Running is widely understood to improve both mental and physical health (Oswald et al., 2020), yet the biomechanical effect of mood on running has been minimally explored. Negativity (sadness, depression, and anger) embodies the person and their movement, observable through walking gait (Michalak et al., 2009), where better mental health has been linked to symmetrical gait (Nagano et al., 2019). Considering the repetitive high impact of running, emotion-driven changes to running mechanics may alter injury risk by changing the musculoskeletal loading experienced by runners. Injury is common amongst runners, with biomechanical symmetry deemed ideal to pre- and rehab injuries (Noyes et al., 1991), and improve running economy (Joubert et al., 2020). High loads experienced at the knee when the foot contacts the ground can potentially lead to knee overuse injuries like patellar tendinitis, patellofemoral pain syndrome (PFPS), and iliotibial band syndrome (ITBS) (Pećina et al., 2001). Asymmetry doesn't guarantee injury but can influence the side that injury occurs (Zifchock et al., 2006). Analysis of mood embodiment in gait is limited to walking, where asymmetry has been observed in emotional expression of happiness, and sadness (Roether et al., 2008), and gait characteristics of anger are stiff, jerky, and hard (Montepare et al., 1999). Research has not yet explored a connection between mood and biomechanical asymmetry during running, which could be valuable for injury prevention. It was hypothesized that asymmetry would increase as an effect of happiness and sadness and decrease as an effect of anger. This study aimed to investigate if mood influences lower-limb biomechanical asymmetry during running.

METHODS: Participants**:** The 13 male and 7 female runners were aged between 21-58 years old (*Mdn* = 43), with average mass of 70.1 ± 9.1 kg, and height of 171.5 ± 7.7 cm. Inclusion criteria required running experience of one year minimum (group range = 3 – 34 years) and completing 60+ minutes per week of running (*M* = 188.95 ± 106.6 minutes), regular running distances of 5+km and being free from injury and illness at the time of data collection. Approval was obtained from the University of Portsmouth's Research Ethics Committee.
Materials: Kinematic data (200Hz) were collected using a 16 camera Qualisys motion capture system, surrounding a motorised treadmill. Sensors were attached to skin or tight clothing with tape, bilaterally on anterior superior iliac spine and posterior superior iliac spine; greater trochanter; medial and lateral epicondyles of the femur; lateral and medial malleolus; posterior calcaneus, distal end of first metatarsal, the first, second and fifth metatarsal heads. In addition, three marker clusters were attached mid-thigh and mid-shank. Mood was assessed using the Brunel Mood Scale (BRUMS) (Terry & Lane, 2010). The questionnaire assesses six subscales, by rating items on a 5-point Likert scale with 0 = not at all, and 4 = extremely, in response to "how do you feel right now?", or in the anger condition to "imagine you are in the same situation;

how does that make you feel?" Mood was elicited using film clips and music that had been previously validated (Seidlecka & Denson, 2019).
Procedure: Participants provided written consent prior, although were not informed of the purpose of the elicitation stimulus and BRUMS until they were debriefed, post data collection, in case it altered responses or behaviour. Participants completed their usual warm up, followed by treadmill familiarization for six minutes (Lavcanska et al., 2005). A repeated measures design was used. The 'baseline' condition was first for all participants, comprising completion of BRUMS, immediately followed by a three-minute running trial. In the first two minutes the speed gradually increased to their 5km pace, ready to capture data in the third minute. The baseline data established the current 'normal' for the individual. The subsequent mood manipulated conditions (anger, happiness, and sadness) were randomised to control learning and fatigue order effects. After each mood manipulation, the running trial was repeated. Every trial was run at their average 5km run pace, ranging between 9.5 -18 kmph (M=12, SD=2.2), ensuring consistency of intensity.
Mood data analysis: A repeated-measures ANOVA with Bonferonni post-hoc comparisons on each of the 6 BRUMS subscales, within-subjects factor of manipulated mood, was used to analyze the mood questionnaire responses and confirm the effectiveness of the stimuli. Participants were identified as non-responders when questionnaire responses did not reflect the expected mood. Mild and full responders displayed the expected mood profiles, but were split by intensity, based on Lane and Terry's (2016) traffic light system that identifies degree of concern in mood changes of athletes.
Asymmetry analysis: Kinematic data were processed in Qualisys Track Manager and filtered using a Butterworth filter with a cut-off frequency of 10Hz. To extract the joint angles with 6 degrees of freedom, skeleton segments were created. Joint angles were defined by the coordinate system relative to the proximal segment (foot relative to the shank; shank to the thigh; thigh to the pelvis; and pelvis to the local coordinate system). Data for one participant was excluded due to marker drop out. Two further participants had comparable data only for either thigh or feet, which were included for analysis. At toe-off, four further participants had missing segment data across one or more conditions, reducing available toe-off data by 11.5%. Joint angles were calculated using the Euler angle ZYZ rotation sequence. Values from the sagittal plane determined the angle of flexion/extension; the frontal plane determined adduction/abduction, and transverse plane determined internal/external rotation, of the ankle, knee and hip for both limbs were identified for each participant in each mood. Angles were taken at events of foot IC and TO, with IC defined as the frame of peak antero-posterior acceleration of the heel marker and TO defined as the frame of peak vertical acceleration of the toe marker (Alvim et al., 2015). Data for the first ten available strides were extracted bilaterally. Paired samples t-tests were run to compare the 10 values between the left and right legs for each variable. Those with significant differences were marked as having significant asymmetry (SigA) (Exell et al., 2012). Asymmetry magnitude for each variable was determined by calculating the Symmetry Angle (SA) (Zifchock et al., 2008), using the mean over 10 strides:

$$SA = (45° - \arctan(X_{Left} / X_{Right})) / 90° \times 100\%$$

A SA of value 0% represents perfect symmetry, where 100% represents equal magnitude, but in opposite directions. Data were discarded for non-responders of each mood condition. The remaining data were split for each mood based on mild or full absorption. Paired samples t-tests were run for both absorption groups to compare the SA scores between baseline and each elicited mood. When normality was violated, Mann-Whitney tests were run. All statistical tests were completed with IBM SPSS version 28 with a significance level of (p < .05) (two-tailed), with Bonferroni correction applied to account for type 1 errors.

RESULTS:
Sadness: The SA significantly increased for full-responders (n = 7) at IC for hip abduction angle by 3.7%, compared to their baseline, (t(6) = 2.59, p = .041, d = .917). The same group at TO showed a significant increase in asymmetry for knee abduction angle by 0.6%, (t(6) = 3.158, p = .020, d = 1.117), and knee internal rotation increased by 1.1%, (t(6) = 2.837, p = .03, d = 1.003), when compared to their baseline. At TO, for sadness mild-responders (n = 8), the SA

significantly decreased for foot rotation angle by 2.7% compared to their baseline, ($t(7) = 2.91$, $p = .023$, $d = .972$), producing reduced asymmetry. There were three non-responders.
Anger: For anger mood mild responders (n = 8) at IC, the SA significantly reduced at hip flexion angle by 0.4%, ($t(7) = -2.39$, $p = .049$, $d = -.797$), and knee flexion angle at TO by 0.2%, ($t(7) = -2.52$, $p = .040$, $d = -.842$), compared to their baseline. Full-responders (n = 8) at TO showed foot plantarflexion SA significantly reduced by 2.2%, ($t(7) = -2.66$, $p = .033$, $d = -.888$), when compared to baseline. There were two non-responders. See Table 1 for details.
Happiness: There were no significant results found for either full (n = 11) or mild responders (n = 3) for the happiness mood. There were six non-responders.

Table 1: Symmetry Angle (SA) Descriptive Statistics for Comparisons Between Mood Absorption and their Baseline for values (a selection of the full table)

			Mood Condition & Absorption Level				Baseline Comparison			
Joint Angle	Event		SigA	Mean (SD)	Min	Max	SigA	Mean (SD)	Min	Max
Hip Abduction	IC	Sad Full*	6	-13.5 (17.9)	-35	15.6	7	-9.8 (16.3)	-27.7	15.7
Hip Flexion	IC	Anger Mild*	7	-4.7 (3.3)	-9.3	-0.1	6	-5.1 (3.2)	-10.1	-1.1
Hip Int-Rotation	TO	Happy Full	7	-2.1 (34.9)	-29.2	74.8	5	-9.3 (14)	-25.1	15.3
Knee Abduction	TO	Sad Full*	6	-5.9 (5.4)	-12.2	3.2	6	-5.3 (5.4)	-11	3.9
Knee Flexion	TO	Anger Mild*	8	-4.7 (1.4)	-6.5	-2.3	5	-4.9 (1.3)	-6.3	-2.8
Knee Int-Rotation	TO	Sad Full*	6	-6.5 (7.8)	-15.9	6.1	4	-5.4 (7.5)	-14.6	6.9
Ankle Abduction	TO	Happy Mild	3	18.2 (1.6)	17.2	20	3	0.6 (30.9)	-35.1	19.7
Ankle Int-Rotation	TO	Sad Mild*	6	-5.8 (22)	-33.9	34.6	8	-3.1 (22.6)	-31.9	37
Ankle Flexion	TO	Anger Full*	7	-6.3 (3.5)	-10.3	-1.5	5	-8.5 (3.3)	-11.8	-3.6

*Key: SigA = Number of participants with significant asymmetries; SD = Standard deviation; Min = Minimum value; Max = Maximum value; Int = Internal; * = significant difference with baseline comparison ($p < .05$)*

Table 2: Median and Interquartile Range ((M(IQR)) for BRUMS Mood Questionnaire Responses

Subscale	Baseline Mood	Angry Mood	Happiness Mood	Sadness Mood	Key
Anger	44 (0) $^{A\,S}$	64 (28) $^{B\,H\,S}$	44 (0) ^{A}	46 (12) $^{B\,A}$	*$^{B\,A\,H\,S}$ denotes which moods*
Confusion	42 (3) $^{A\,S}$	51 (32) $^{B\,H}$	42 (11) ^{A}	48 (15) ^{B}	*significant differences*
Depression	43 (0) $^{A\,S}$	62 (19) $^{B\,H}$	43 (0) $^{A\,S}$	57 (23) $^{B\,H}$	*exists between, ($p < .05$)*
Fatigue	45 (7)	41 (11)	40 (4)	42 (7)	*^{B} = Baseline, ^{A} = Anger,*
Tension	42 (7) ^{A}	53 (33) $^{B\,H}$	42 (0)	46 (7)	*^{H} = Happiness,*
Vigour	55 (10) $^{A\,S}$	50 (10) $^{B\,H}$	58 (11) $^{A\,S}$	45 (15) $^{B\,H}$	*^{S} = Sadness*

DISCUSSION:
The aim of this study was to establish if mood influences lower-limb biomechanical asymmetry during running. The results indicate a small connection between the symmetry of several biomechanical variables and mood. Asymmetry differences found for sadness full responders of hip abduction at IC, and knee abduction and internal rotation at TO are characteristics of contralateral hip drop and could potentially lead to injuries like PFPS or ITBS over time (Gandbhir et al., 2021). Excessive knee internal rotation is characteristic of knee valgus, and contributes to PFPS, although asymmetries in the contributing characteristics of hip adduction and internal rotation were not found in this study. This partially accepted the hypothesis that asymmetry would increase in the presence of sadness and happiness. Despite asymmetry changes being small, the high number of ground impacts experienced by distance runners could lead to cumulative overload and increased injury risk due to the reported asymmetry. Happiness may have had no effect on asymmetry, or the mood profile was too similar to baseline's mood profile, to show any differences, see Table 2. Table 1 shows two occurrences where the happiness condition had a larger SA than its baseline comparison, ankle abduction at TO for mild responders changed by 17.6% (n = 3), and hip internal rotation at TO for full responders changed by 7.2% (n = 7); however, neither of these were statistically significant.
Anger full and sadness mild responders had significantly reduced asymmetry, partially accepting the hypothesis because this was not expected with sadness. Anger stimulates the sympathetic nervous system, which stiffens muscles and joints, contributing to reduced asymmetry, and supporting existing theory that anger facilitates performance (Lane & Terry, 2001). Reduced asymmetry in knee kinematic variables occur because of fatigue (Radzak et al., 2017), producing more efficient movement, and may be why reduced asymmetry occurred for mild sadness responders.

Overall, the stimuli were accepted as eliciting the desired mood, since the relevant BRUMS subscales depicted each mood state. However, this study is limited by the strength of the stimulus at evoking realistic emotional intensity. Watching a film clip is not as powerful as personal experience, especially with anger (Siedlecka & Denson, 2019). Future research should consider adopting an autobiographical approach that focuses on an emotive memory. Further, self-report scales may not show an accurate representation of mental health if emotions are not understood or when disengaged from high arousal negative emotions.

CONCLUSION: This study suggests that mood influences lower-limb biomechanical asymmetry during running. To the author's knowledge this is the first study to explore mood embodiment when running. A sad mood amplified asymmetry in hip abduction, knee abduction and knee internal rotation, which could lead to overuse injuries following repeated impacts during running. An angry mood produced a more symmetrical gait due to reduced degrees of freedom, suggesting increased stability. Asymmetry differences were small, yet this may be more detrimental to those with existing asymmetries than those without, suggesting the positive mental health benefits of running in a sad mood may outweigh the risk. Monitoring mood and adapting training accordingly may empower runners to stay injury free. Running with a friend at a slower conversational pace may help to manage a sad mood by reducing impacts force.

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