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QUANTIFYING MECHANICAL LOADING DURING TRAINING IN TRACK ATHELTES

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The present study investigated the potential of inertial sensors to objectively quantify mechanical load during training in track athletes. Three female sprinters wore a single inertial sensor attached to the distal tibia during identical training sessions on two separate occasions. Objective measures of the 'relative' mechanical loading (acceleration integral expressed per second) obtained from the inertial sensors were highly correlated with increases in running velocity and indicated excellent repeatability across the two sessions. Quantifying mechanical loading during training using this technology appears viable and may provide important insights into differences in training loading within and between individuals. Such training load measures may assist in identifying increased injury risk in high level track and field athletes.

KEY WORDS: mechanical load, accelerometer, high-level athletes, track and field.

INTRODUCTION: Among high-level track and field athletes, the potential negative impact of musculoskeletal injury on training and competition progression presents a very real challenge. Research into injury incidence among Australian track and field athletes indicates a high number of injuries (76% of athletes injured within a 12 month period) with the majority of injuries occurring in the leg, thigh and knee (Bennell & Crossley, 1996). Of these injuries, the most common injuries were stress-related overuse injuries and hamstring strains with the rate of injury recurrence exceeding 30%.

Research into lower limb overuse injuries and stress fracture in females involved in high-impact sports, such as track and field, suggests a number of potential risk factors including exposure to increased loading (Bennell, Matheson, Meeuwisse & Brukner, 1999; Jones, Thacker, Gilchrist, Kimsey & Sosin, 2002). Increased training load exposure is also implicated in increased lower limb soft tissue injury risk (Yeung & Yeung, 2001). It's postulated that overuse injury development, in particular stress fracture, may be more dependent on loading magnitude than loading exposure (Edwards, Taylor, Rudolphi, Gillette & Derrick, 2010). Therefore, it's not just the training load, but the magnitude of the loading that appears important in injury risk exposure among athletes. With ground reaction forces during high-impact sports, such as jumping in track and field, potentially reaching fourteen to fifteen times body weight (Perttunen, Kryolainen, Komi & Heinonen, 2000), the impact of mechanical loading during these sports is not surprising. However, despite the high forces involved and the apparent link between the relative mechanical loading of high-impact sports and increased injury risk, research into the relationship between ground reaction forces and overuse injuries in athletes provides conflicting findings (Grimston, Engsberg, Kloiber & Hanley, 1991; Crossley, Bennell, Wrigley & Oakes, 1999; Bennell et al., 2004; Willems, Witvrouw, De Cock & De Clercq, 2007).

The assessment of both the magnitude and volume of mechanical load experienced during daily training may provide a clearer picture of the relationship between training loading and injury. Additionally, it may be the change in mechanical loading experienced both between individual training sessions and training cycles that may be of more importance in stress-related injury risk.

With the advancement of technologies available, the use of inertial sensors to measure mechanical loading during actual training sessions may provide an important link in understanding the relationship between impact loading and potential increased injury risk.

The purpose of the present study was to assess the feasibility of using inertial sensors with high level track and field athletes to obtain an objective measure of the relative mechanical loading experienced during a training session. It was anticipated that differences in mechanical loading would be identified and reflect differences in running velocity within a single training session and additionally be able to show differences in loading between athletes. Similar training load scores were expected for each athlete across training sessions at the same relative intensities.

METHODS: Three State and National level female sprinters (Table 1) completed two identical training sessions one week apart. An inertial sensor (Nanotrak, v6.67, Catapult, VIC) was attached to the distal tibia of participants, secured using double-sided adhesive and strapping tape during participant's normal training sessions. The unit started sampling data at the commencement of training and was stopped following the conclusion of the session. During each session participants completed a 50m run and at 5 different intensities. Participants were instructed to run at the following intensities; jog, 60%, 70%, 80% and 90% of maximum. Participants ran together at the same pace and completed each trial of the drill at the same time. The times for each 50m trial were recorded to determine running velocity. Participants were tested on two occasions, one week apart, and ran on grass for both sessions.
This study was approval by the Australian Institute of Sport Ethics Committee, and informed consent to use anonymous data for research purposes was obtained from all participants.

Table 1
Athlete details and personal best (PB) times.

	Athlete 1	Athlete 2	Athlete 3
Height (m)	1.70	1.72	1.70
Mass (kg)	54.7	57.3	59.0
100m PB (s)	----	11.85	12.75
200m PB (s)	23.93	24.10	26.44
400m PB (s)	52.95	----	----

Data from the sensors were downloaded to computer and converted to a text file using commercial software (Logan, v35.8, AIS, Canberra). The text file was opened using customised Labview software developed to analyse the accelerometer data.
The start of the sample period was determined as the start of acceleration, which was clearly visible from the data. The time to complete the 50 m trial was used to determine the sample period from the initial acceleration. Acceleration in the vertical dimension was analysed for each trial during the period of the 50 m run. Over this sample period the data was rectified prior to calculation of 'Mechanical Load' parameters. The acceleration integral was determined to represent 'Mechanical Load' (ML), and the acceleration integral divided by the data sample period in seconds was determined to represent the 'Relative Load' (RL) per unit time.
Correlations between the load measures and running velocity were conducted within individuals for both sessions to assess the ability of the inertial sensors to discriminate between running velocity and mechanical load. One-way Analysis of Variance (ANOVA) measures were used to assess any significant differences between athletes within each session and across both days. Correlations and ANOVA analysis were conducted using the Statistical Package for Social Sciences (SPSS, v18.0). Intraclass correlations and coefficient of variation scores expressed as a percentage of the mean (CV%) were calculated from the log-transformed data using a custom spreadsheet (Hopkins, 2012).

RESULTS: The results for both the ML and RL for each 50m interval across both training sessions are contained in Table 2. The running velocities recorded for all atheltes across each of the five intensities were 4.81 m/s, 5.38 m/s, 5.75 m/s, 6.49 m/s and 6.85 m/s during session 1 and 4.88 m/s, 6.22, 6.40, 6.92 and 7.16 m/s during training session 2.

Table 2
Mechanical Load (ML) and Relative Load (RL) measures for each athlete during each 50m effort from two repeat training sessions.

		Athlete 1		Athlete 2		Athlete 3	
		ML	RL	ML	RL	ML	RL
	Jog	23.12	2.22	29.16	2.80	23.53	2.26
	60%	25.91	2.79	28.62	3.08	26.98	2.90
23/10/12	70%	26.22	3.01	29.22	3.36	27.45	3.16
	80%	25.18	3.27	28.53	3.70	27.15	3.52
	90%	25.47	3.49	28.70	3.93	27.22	3.73
	Jog	23.29	2.27	27.33	2.67	20.14	1.97
	60%	24.10	3.00	25.53	3.18	21.13	2.63
30/10/12	70%	24.54	3.14	25.42	3.26	21.83	2.79
	80%	23.95	3.31	25.23	3.49	23.01	3.18
	90%	24.64	3.53	26.60	3.71	23.18	3.32

The RL (the integral of the vertical acceleration expressed per second) was highly correlated to average running velocity for each athlete, with r-values of between 0.89 and 1.00 (Table 3). In contrast the ML measures (vertical acceleration integral), displayed varying correlation coefficients when related to running velocity with r-vales ranging from -0.58 to 0.96 (Table 3).

Table 3:
Correlation coefficients between both the vertical Relative Load (RL) (acceleration integral divided by time) and vertical Mechanical Load (ML) (acceleration integral) with running velocity for both test sessions for three participants.

	Athlete 1		Athlete 2		Athlete 3		Combined	
	23/10/12	30/10/12	23/10/12	30/10/12	23/10/12	30/10/12	23/10/12	30/10/12
ML	0.26	0.18	-0.58	-0.58	0.72	0.96*	0.26	0.18
RL	0.92**	0.89**	1.00**	0.99**	0.98**	0.99**	0.92**	0.89**

* significant correlation, $p<0.05$; ** significant correlation, $p<0.01$

Analysis of Variance (ANOVA) results indicated a significant difference between athlete ML measures within both training sessions (Session 1: $F(2,12)=12.07$, $p<0.01$; Session 2: $F(2,12)=23.69$, $p<0.01$) and when the data was pooled across both days ($F(2,27)=8.10$, $p<0.01$). Although approaching significance for the pooled data, no ANOVA analysis indicated a statistically significant RL measure between athletes (Session 1: $F(2,12)=0.86$, $p>0.05$; Session 2: $F(2,12)=1.32$, $p<0.05$; Overall: $F(2,27)=1.76$, $p>0.05$).
Intraclass correlation and coefficient of variation results indicate excellent reliability for the RL measure across mutliple sessions (ICC: 0.93, CV%: 4.9). Less apparent reliability was indicated for the more 'global' ML measure (ICC: 0.62, CV%: 5.2).

DISCUSSION: Given the results of the present study, the use of inertial sensors to measure mechanical loading in high level track and field athletes appears promising. RL measures obtained from inertial sensors were able to objectively identify differences in mechanical loading associated with different running velocities during training in the three sprinters measured in the present study. Additionally, RL measures appear stable displaying excellent repeatability across two identical training sessions. ML measures did not appear able to objectively discriminate between running velocity within a session and although reporting good reliability according to the coefficient of variation results, showed less reliability in intraclass correlation results.

Interestingly, ML appeared able to show differences in loading measures between athletes across both sessions. RL measures however, were unable to statistically discriminate any potential difference in loading between athletes, although some athlete differences in RL magnitude are apparent.

The inability of ML measures to differentiate between running velocity was somewhat surprising. It was anticipated that increases in running velocity would be ‘mirrored’ by subsequent increases in tibial acceleration leading to increased ML values. Although there were increases in the magnitude of tibial acceleration during faster runs, this appeared to be offset by the reduced duration of the run resulting in a similar ML value for each repetition. Despite the apparent limitations of the ML measure in the present study, total vertical load may still be a useful measure when comparing mechanical load within an entire training session across different types and phases of training. Conversely, these findings may indicate that the intensity (magnitude per time) may be of more importance for athletes than the volume of mechanical loading (magnitude only). Further investigation into potential links between these measures and injury risk among athletes would be of interest.

Further investigation into the potential of this technology and methods to track mechanical loading differences within and between athletes appears warranted. Differences in these measures appear to have the potential to provide insights into possible injury mechanisms in high-load, high level athletes such as track and field. Future research applying these measures across different modalities of training may provide further insights into mechanical loading during training. In addition, ongoing monitoring of mechanical loading using inertial sensor technology may be beneficial. In may be of more importance to objectively measure changes in mechanical loading within an athlete across multiple session and training phases as a potential precursor to injury than differences between athletes alone.

CONCLUSION: The integrated vertical acceleration as measured by inertial sensors appears able to provide good measures of mechanical loading in track and field athletes and was able to consistently discriminate between running velocities across multiple repetitions and sessions. Longitudinal research incorporating these measures as an indication of mechanical loading appears possible and such measures may provide valuable information on possible injury mechanisms in high-level, high-load athletes.

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