Effect of Kinesiology Tape on Tri-Axial Accelerometry During the Dance Aerobic Fitness Test

Stephanie Moulder, BSc, Ross Armstrong, PhD, Matt Greig, PhD, and Chris Brogden, PhD

Abstract

Objectives: Kinesiology tape (KT) is thought to provide greater mechanical support during physical activity, however, there is a paucity of research investigating its application in dance. The study aimed to determine whether KT reduces PlayerLoad (PL) during the Dance Aerobic Fitness Test (DAFT) in addition to examining the relative sensitivity of accelerometer site locations.

Methods: University-level dancers (N = 11; age 18 ± 0.45 years, height 168.17 ± 12.25 cm, body mass 57.50 ± 9.91 kg) participated in two trials of the DAFT protocol in two conditions: no tape (NT) and kinesiology tape (KT). Global positioning systems (GPS) and accelerometer units were attached onto the seventh vertebra (C7) at the mid-scapula region and lower limb (LL) located at the mid-gastrocnemius of the dominant leg calculating measurements of triaxial (PL_{Total}) and uniaxial measures (anteroposterior [PL_{AP}], mediolateral [PL_{ML}], and vertical [PL_{V}]) measures of PlayerLoad during the DAFT.

Results: No significant main effect was observed for the taping condition in all measures of PlayerLoad ($P > 0.10$). A significant main effect ($p < 0.01$) was observed for unit location and time, with greater loading at the LL compared to C7 and during each consequent stage of the DAFT. No significant ($p > 0.52$) location*taping, nor location*taping*time ($p > 0.36$) interactions were observed for all variables measured.

Conclusions: Kinesiology tape does not reduce loading patterns in healthy dancers during a fatigue protocol. However, triaxial accelerometers provide adequate sensitivity when detecting changes in loading, suggesting the LL may be deemed as a more relevant method of monitoring training load in dancers.

Classical dance is known to be associated with numerous health benefits consisting of flexibility,[1] muscular endurance and power,[2] strength and tone,[3] and balance.[4] Despite these benefits, injury rates remain high across genres with rates in ballet dancers ranging from 0.62 injuries per 1,000 hours of dance[5] to 0.77 injuries per 1,000 hours[6] and 1.38 injuries per 1,000 hours.[7] In university dance students performing contemporary dance, ballet, and jazz, injury rates of 1.03 injuries per 1,000 hours[8] have been reported. While injury rates of 4 injuries (modern), 1.8 injuries (Mexican folkloric), and 1.5 injuries (Spanish dance) per 1,000 hours training have been reported.[9]

Injury can result in complications with health, fitness, mental well-being, and financial issues.[10,11] Up to 62% of all injuries reported within pre-professional and professional dancers are localized to the foot and ankle complex.[12-15] The majority of injuries sustained during dance are caused by an inability to absorb ground reaction forces when performing jumps and landing movements,[12] and this repetitive overload can increase the risk of chronic injury development due to microtrauma. Changes in movement patterns have been identified in dancers in a fatigued state,[16] which may potentially lead to injury. Chronic fatigue is associated with the prevalence of overuse as a mechanism of injury in dancers, representing 56% to 57% of dance injuries.[5,17] Injuries in dancers tend to be chronic as opposed to acute,[18,19] with common pathologies including snapping hip syndrome, ligament sprain, tendinosis, and stress fracture.[19,20] Furthermore, classical dance has been shown to affect the development of chronic health conditions such as osteoarthritis,[21] suggesting an association between chronic overuse injuries and impact loading,[15,22] and thus highlighting the need to monitor training loads in dance disciplines[12,23] and to investigate interventions such as taping

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that may influence mechanical loading. Injury risk is further exasperated because dancers will often work through pain,[12] which aggravates symptoms and increases severity.[24]

The use of triaxial accelerometers has been found to be an effective technique for monitoring athlete performance, with research presenting the PlayerLoad metric as a reliable and valid tool within laboratories and sports settings.[25,26] The triaxial accelerometers (MinimaxX) produce frequency and magnitude PlayerLoad scores through three individual planes; anterior-posterior (AP), medial-lateral (ML), and vertical (V). Previous research has suggested a link between increased accumulated PlayerLoad and injury incidence.[27] However, to date few studies have produced findings in relation to the placement position of the accelerometers, with the majority of studies choosing to place the GPS unit at the mid-scapulae position,[28,29] which holds little relevance to biomechanical loading in dancers and injury epidemiology.[30,31]

Monitoring training loads is essential for assisting with interventional landing or loading strategies to reduce injury incidence.[32-34] Taping strategies and their effectiveness in reducing injury risk have been extensively researched, with literature providing many equivocal and contrasting findings.[32,34,35] However, KT differs to that of traditional adhesive taping, as it can be used to stabilize and support the ankle joint without joint motion restriction.[36] Kinesiology tape is an elastic strip made from 100% cotton that is latex free and combined with adhesive, designed to mimic the elasticity of a healthy muscle, allowing for a stretch of up to 140% of its original length. This increase in stretch is claimed to provide a pulling force on the skin,[36] thus providing greater mechanical support and proprioceptive ability via stimulating mechanoreceptors and muscle activation patterns.[37] Furthermore, KT is suggested to increase blood flow[38] and reduce pain,[32-34] and equivocal results suggest that KT may help to reduce ground reaction forces (GRF) when jumping and landing.[39,40]

There is insufficient research in dance evaluating the use of GPS accelerometery and interventional strategies such as KT.[31] Consequently, the primary aim of the study was to determine whether KT reduces PlayerLoad during an incremental dance fitness test. The secondary aim of the study was to examine the relative sensitivity of accelerometer site locations, given the prevalence of lower-limb injuries in dance. Based on purported knowledge of KT, it was hypothesized that a decrease of PlayerLoad will occur in classical dancers. It is also hypothesized that a greater mechanical load would be observed in the LL when compared to the C7 placement.

Materials and Methods

Study Design

This study consisted of a repeated measures design to investigate the effects of KT and no tape (NT) and accelerometer unit position while participants performed the Dance Aerobic Fitness Test (DAFT). Independent variables included: taping condition, NT and KT along with unit location, lower limb (LL), and seventh cervical vertebrae (C7). The dependent variables included: heart rate (HR); rate of perceived exertion (RPE); triaxial load (PL_{Total}); and uniaxial load in medial-lateral (PL_{ML}), anterior-posterior (PL_{AP}), and vertical (PL_V) axes. Participants attended the university dance studio on three occasions to complete a familiarization trial of the DAFT according to the guidelines and routine provided, followed by two experimental trials (KT and NT) in a randomized order, with a minimum of 72 hours rest between all trials. All trials were conducted at the same time of day (12:00 pm) to avoid any variation in performance due to changes in circadian rhythms. Participants attended the dance studio in a 3-hour post-absorptive state following a 24-hour abstinence from vigorous exercise and alcohol and caffeine consumption and while wearing the same light weight athletic clothing for each trial. Each trial was conducted in bare feet. Participants were instructed through a thorough warm-up prior to testing. This included a 10-minute pulse raiser consisting of circular walking, jogging, and skipping followed by dance specific stretching that included a series of demi and full pliés at the bar and a series of tendus and grand battements both executed on each side.[41] The subjects then proceeded to perform the instructed DAFT protocol. Following performance of the DAFT, a cool-down was commenced with 3 minutes of light jogging followed by 2 minutes of static stretching that included lunges, side stretches, and calf stretches.

Participants

Eleven dancers enrolled in a university dance degree program who, due to the holistic nature of their coursework, participated in the genres of contemporary dance, ballet, and jazz were recruited to participate in the study (age: 18 ± 0.45 years; height: 168.17 ± 12.25 cm; body mass: 57.50 ± 9.91 kg). Pre-testing information was compiled regarding the participant's injury history, general health, and previous history of taping. Inclusion criteria required participants to be enrolled in an undergraduate degree program in dance in which dance activity was performed for 15 hours per week, be between 18 and 24 years of age, have a minimum 5 years of previous dance experience, be injury free in the lower limb for at least 6 months prior to testing, have no history of cardiovascular or pulmonary complaints, and have no neurologic or balance disorder or chronic ankle instability as determined by the Cumberland Ankle Instability Tool.[42] Failure to adhere to requirements or ill health caused the participant to be excluded from testing. Ethical approval was provided by the University Ethics Committee in accordance with the Declaration of Helsinki 1975.

Procedures

Dance Aerobic Fitness Test

The DAFT is considered a reliable measure of the physiological ability of

Table 1 Dance Aerobic Fitness Test Choreography

Level	Tempo ($b \cdot min^{-1}$)	Movement
1	68	5 steps, plié, and recover. 4 sets of 2 pliés, with 90° turn between each set.
2	78	5 steps, plié, and recover. 3 spring hops in a circle. 4 sets of 2 pliés with 90° turn between each set, arms moving between first and second position.
3	78	5 steps, plié, and recover. 3 spring hops in a circle with arm movements added (one arm in second position, opposite arm circles overhead). 4 sets of hop plié with 90° turn between each set, arms moving between first and second position.
4	94	5 steps, plié, and recover. 3 spring hops in a circle with arm movements (one arm in second position, opposite arm circles overhead). 4 sets of hop-hop with 90° turn between each set, arms moving between first and second position.
5	108	5 springs, plié, and recover. 3 spring hops in a circle with arm movements (one arm in second position, opposite arm circles overhead). 4 sets of hop-hop with 90° turn between each set, arms moving between first and second position.

dancers to cope with aerobic demands during dance sessions.[43] The 16-beat sequence protocol consists of five 4-minute levels, each accumulating additional movement and increasing in intensity (Table 1). Participants were eliminated from the test if two trained dance professionals agreed that they moved behind the beat of the test or if movements became compromised (e.g., pointed feet, consistent arm positions, jump height, plié depth, coordination sequencing, and travelling distance). This need for agreement was utilized to strengthen the methodology.

Physiological and Perceptual Measurements

Physiological response to each intensity level of the DAFT protocol was measured in terms of HR and RPE. Subjective ratings of perceived exertion were identified at the end of each level by means of Borg's 6-20 scale[44] with HR telemetrically recorded through MinimaxX global positioning systems (Catapult, Melbourne, Australia).

Accelerometry

Triaxial accelerometer (Kionix KX94, Kionix, Ithaca, New York, USA) data were sampled at 100 Hz and stored in a MEMS unit (MinimaXx S4: Catapult Innovations, Scoresby, Australia). To reduce movement artefacts, a neoprene vest was used to hold the MEMS device at the position of the C7 cervical vertebra. An adapted neoprene garment was used to house the lower limb (LL) MEMS device, located at the mid-gastrocnemius of the dominant leg, identified as 50% of the distance between the posterior calcaneus and the posterior part of the femoral condyles. The dominant leg was determined as that used by the participant to kick a ball.[45] The neoprene vest was applied directly to the skin and secured with under-wrap both above and below the MEMS device. PlayerLoad at both C7 and LL was calculated as the square root of the instantaneous rate of change in acceleration in each of the three planes of movement (medial-lateral [PL_{ML}], anterior-posterior [PL_{AP}], and vertical [PL_{V}]).[23] PlayerLoad Total (PL_{Total}) was calculated by the summation of the uniaxial PlayerLoad values recorded in each of the movement planes to provide a triaxial PlayerLoad value.

Kinesiology Tape

Kinesiology tape was applied and removed in accordance to the guidelines.[46] Prior to application, the area was cleaned and dried thoroughly using alcohol gel to better allow the tape to adhere to the skin.[47] In accordance to the KT application guidelines, a functional corrective taping strategy was applied by a certified KT practitioner to the individual's dominant limb to assist dorsiflexion and eversion as shown in Figure 1. The participant lay supine on a plinth with the first strip of tape placed from the anterior mid foot and stretched over the tibialis anterior at approximately 115% to 120% stretch of its maximal length, attaching distal to the anterior tibial tuberosity. The second strip started proximal to the medial malleolus, wrapped around the heel like a stirrup, and attached lateral to the first strip of tape. The third strip stretched across the anterior portion of the ankle, covering both the medial and lateral malleolus. The fourth and final strip began at the arch of the foot and stretched slightly above both the medial and lateral malleolus. Manual stretch was only applied to the mid potion of the KT,[48] while testing was delayed from starting for a period of 25 minutes in

Figure 1 Kinesiology tape application to the ankle joint (Brogden and Greig, 2014).

Table 2 Time History Changes for Uniaxial and Triaxial Accelerometry Measures Across Levels of DAFT Performance

	Level 1	Level 2	Level 3	Level 4	Level 5
PL_{AP}*	11.12 ± 4.67 95% CI 10.51-11.73	13.66 ± 6.09 95% CI 12.80-14.51	22.10 ± 10.54 95% CI 20.65-23.54	32.39 ± 13.64 95% CI 30.35-34.43	37.26 ± 95% CI 35.39-39.14
PL_{ML}*	12.90 ± 6.74 95% CI 12.40-13.40	15.64 ± 8.32 95% CI 14.92-16.36	21.76 ± 11.46 95% CI 20.85-22.67	30.92 ± 16.21 95% CI 29.22-32.63	36.30 ± 19.37 95% CI 34.45-38.15
PL_{V}*	12.16 ± 3.79 95% CI 11.53-12.78	15.02 ± 4.83 95% CI 14.17-15.86	28.00 ± 13.17 95% CI 26.34-29.66	42.64 ± 18.61 95% CI 39.47-45.80	50.54 ± 20.90 95% CI 47.50-53.58
PL_{Total}*	35.89 ± 15.01 95% CI 34.30-37.49	43.73 ± 18.18 95% CI 41.45-46.00	71.29 ± 26.21 95% CI 67.56-75.01	105.26 ± 43.48 95% CI 98.84-111.68	123.81 ± 46.41 95% CI 117.65-129.98

*Denotes a significant difference with all other time points

order to allow the tape to gain its full adhesive strength.[49]

Statistical Analysis

All data are reported as mean and standard deviation unless otherwise specified. Before parametric analysis, the assumptions of normality were verified using the Shapiro-Wilk test. Differences of the physical responses recorded between levels of the DAFT were analyzed using a repeated measures general linear model (GLM). Where appropriate, post-hoc analyses with a Bonferroni correction factor were applied. Confidence intervals (95% CI) and Cohen's d effect sizes are also reported for significant findings. All statistical analyses were completed using PASW Statistics Editor 22.0 for Windows (IBM SPSS Statistics software, IBM, Armonk, New York, USA), with significance level set at $p \leq 0.05$.

Results

Tape

Tape demonstrated no significant main effect for uniaxial variables PL_{AP} ($p = 0.20$), PL_{ML} ($p = 0.10$), PL_V ($p = 0.20$), and triaxial variable PL_{Total} ($p = 0.26$).

Time History Changes of DAFT

Table 2 displays the time history changes across the DAFT protocol for triaxial measures of PL_{Total}, with the GLM identifying a significant ($p \leq 0.001$) main effect for time at each subsequent level of the DAFT. As illustrated in Table 2, similar results were observed for uniaxial measures of PL_{AP}, PL_{ML}, and PL_V ($p < 0.01$), with significantly greater values of PlayerLoad observed at each successive stage of the DAFT protocol. However, no significant ($p > 0.10$) tape*time interactions were demonstrated for any accelerometry measures recorded.

Location

As identified in Figure 2, a significant ($p < 0.01$) main effect for unit location was detected for triaxial measures of PL_{Total}, producing significantly increased loading at the LL when compared to C7.

Equivalent patterns ($p < 0.01$) of increased loading at the LL where observed for uniaxial measures of PL_{AP}, PL_{ML}, and PL_v. As highlighted in Figure 3, significant location*time interactions ($p < 0.001$) were identified for uniaxial variables PL_{AP}, PL_{ML}, PL_V and triaxial variable PL_{Total} for each stage of the DAFT, with C7 consistently underestimating the level of loading experienced by the participants. The LL location highlighted a main effect for location with increased levels of sensitivity ($p < 0.001$) identified for measures of PL_{AP}, PL_{ML}, PL_v, and PL_{Total} when compared to C7. Furthermore, the sensitivity of the devices to detect changes in uniaxial and triaxial measures of load highlighted significant main effects for time ($p < 0.001$) for all variables measured.

No significant location*tape interactions were recorded for uniaxial measures of PL_{AP} (C7: $p = 0.50$; LL:

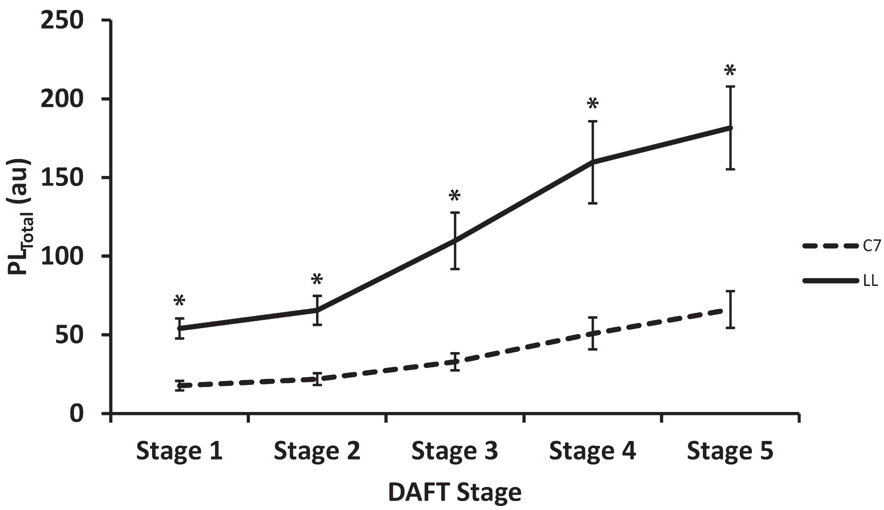

Figure 2 PL_{Total} time history changes across the DAFT. * denotes a significant ($p < 0.05$) response to each time point.

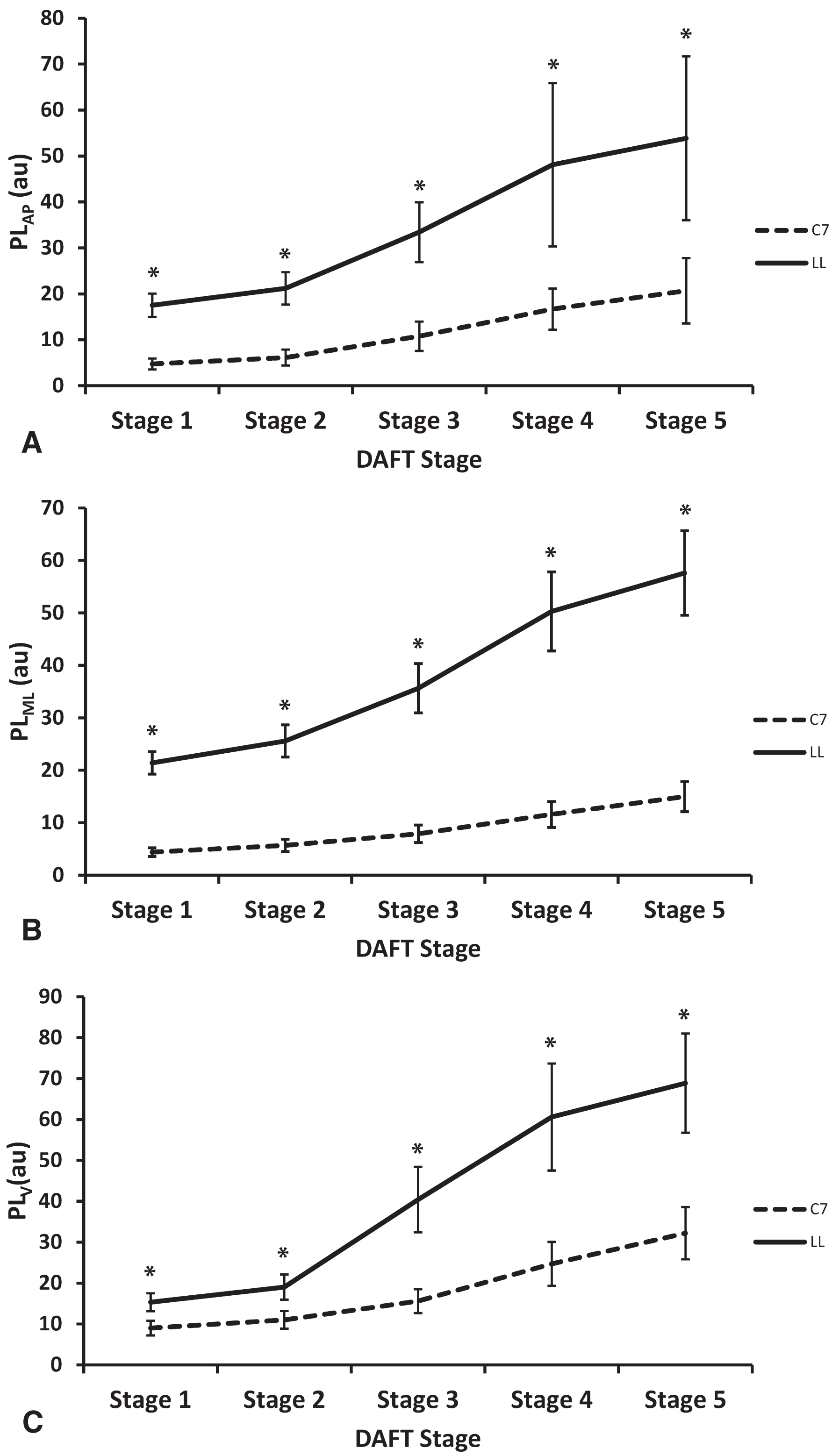

Figure 3 Uniaxial PlayerLoad response for **A**, PL_{AP}, **B**, PL_{ML}, and **C**, PL_V at C7 and LL during the DAFT. *Denotes a significant time*location interaction with the respective time point.

$p = 0.25$), PL_{ML} (C7: $p = 0.52$; LL: $p = 0.09$), and PL_V (C7: $p = 0.61$; LL: $p = 0.19$) and triaxial measures of PL_{Total} (C7: $p = 0.81$; LL: $p = 0.16$).

Furthermore, no significant ($p > 0.36$) time*tape*location interactions were identified for any accelerometry variables recorded.

Physiological and Perceptual Response

Physiological and perceptual responses to the protocol are demonstrated in Table 3. The test revealed a significant main effect for time ($p < 0.01$) with a significant increase in HR observed at each subsequent level of the DAFT. No significant main effect for tape ($p = 0.39$) nor tape*time ($p = 0.43$) interactions were observed.

As highlighted in Table 3, a significant main effect for time ($p < 0.01$), was observed for RPE with higher values recorded as the DAFT increased in intensity. No significant main effect for tape ($p = 0.96$) nor tape*time ($p = 0.69$) interactions were observed.

Discussion

The primary aim of this study was to determine the effects of KT on PlayerLoad response during the DAFT, with a secondary aim of investigating the sensitivity of accelerometer unit locations. The main findings include: 1. KT had no significant effect on uniaxial or triaxial variables of PL during the DAFT, and 2. all triaxial and uniaxial measures of PL indicated a significantly greater relative loading at the LL compared to C7. The findings of the current study support the hypothesis that greater mechanical loading will be observed at the LL, however the hypothesized reduction of PL with KT applied is rejected.

It has previously been hypothesized that KT helps to decrease relative loading in athletes during activity through the proposed mechanism of providing support to the muscles and joints through lifting the layers of the skin.[32-34,40] In contrast, no significant differences existed between taping conditions for all PL metrics throughout for $C7_{NT}$ and $C7_{KT}$. This supports the findings of Hendry et al.[39] who reported no significant difference in knee or hip forces when dancers performed discrete drop landings in both KT and NT conditions and is supported by the previously reported lack of a significant effect of KT on GRF[50,51] interaction between location and taping condition at all five stages. In contrast to this study and previous

Table 3 Physiological and Perceptual Response to the DAFT Protocol

DAFT Level	HR (b·min^{-1})	RPE (au)
1	137 ± 8*	7 ± 1*
2	149 ± 10*	9 ± 2*
3	171 ± 7*	12 ± 1*
4	179 ± 7*	15 ± 1*
5	186 ± 6*	18 ± 1*

*Denotes a significant main effect with all other time points.

literature,[39,50,51] a positive reduction of mechanical loading and GRF has been observed when applying KT to participants.[40] However, the reduction in kinetic forces and loading was observed in participants who suffer from functional ankle instability who may benefit more from this increase in sensory input to the skin when compared to healthy participants.[52,53] This suggests that KT may provide increased support via reducing mechanical loading, however, it may lack a similar effect in non-injured participants.[53]

It could be potentially argued that the proposed effects of KT on muscle activation may be responsible for a non-significant difference.[50,54] Several studies have discussed the potential for KT to increase muscle activity, which may increase muscle spindle sensitivity through stimulation of cutaneous mechanoreceptors and influence joint loading.[50,51,54] The production of a more powerful output via such action may consequently discard a positive effect on structural support and, therefore, potentially cause no significant changes in mechanical loading. However, this study did not account for muscle activation measurements, therefore, future research may benefit from using electromyography (EMG) to produce better scientific understanding of KT's effects.[50]

Application of triaxial accelerometry within dance is an innovative approach. However, this study suggests that the units have adequate sensitivity at both C7 and the LL for detecting loading pattern changes throughout an incremental standardized dance performance, but the LL appears to be able to identify a greater magnitude of change in uniaxial and triaxial values. Significant increases in PL were observed at each stage of the DAFT, which is in agreement with the findings of Brogden et al.[31] This may be a result of previously purported increases in GRF with greater intensity of movement patterns and tempo observed in the DAFT protocol through increased difficulty of steps leading to elevated movement patterns at each subsequent stage.[55,56] The current study also observed corresponding findings for physiological and perceptual responses, with the data demonstrating a significant increase in both HR an RPE at each subsequent level of the DAFT. These results support earlier findings that indicated that accelerometer units deliver appropriate sensitivity to detect loading pattern fluctuations during fatigue protocols.[31,57] Such judgment is important in monitoring large training volumes in classical dance due to the large association between overuse injuries and impact loading.[12,15,27]

When measuring mechanical loading, significantly greater results were observed at the LL location when compared to C7 for all PL metrics, with quantified increases of 67%, 77%, 56%, and 66% found for PL_{AP}, PL_{ML}, PL_{V}, and PL_{Total}, respectively. These findings are comparable to studies that have investigated alternate placement position of accelerometer units at more distal anatomical locations.[29,31] The increase in LL loading demonstrates associations with GRF that concurs with previous results[58,59] that demonstrated a significant relationship during a vertical jump when placing the units at the fibular head. Such findings could possibly indicate that the lower proximity to the ground represents vertical translation and ground contact experience during high velocity allegro components throughout the DAFT resulting in greater mechanical loading.[12,31] Previous research demonstrated a requirement for more precise unit locations due to poor reliability when measuring whole body acceleration.[60] Heart rate values during the DAFT were similar to those previously reported.[8,61]

The majority of injuries are sustained in the lower extremity.[7,12-14] Therefore, accelerometer units placed at the LL is associated with increased loading, which may provide a more accurate result to determine changes within the LL when compared to placement at C7. Thus, it provides a more practical method of measuring the distribution of loads in dancers.[30,31] The measurement of LL PL enables a greater understanding of injury risk in classical dancers due to the high association between excessive loading patterns and injury incidence.[15,27,28] An untreated dysfunction at one kinetic chain location can result in a compensatory dysfunction at other locations.[12] The repetitive nature of dance requires movement pattern monitoring to prevent abnormal joint loading as the repeated absorption of energy over time may create forces that the dancer is unable to withstand. Consequently, accelerometer units may deliver valuable quantitative feedback on loading patterns, allowing the modification of excessive loads and training protocols and, thus, potentially decreasing risk of injuries within dance.[27,31] However, caution should be noted as PL is not directly related to the magnitude of acceleration, rather it is determined by the rate of change of acceleration. Thus, accelerometry can be used as tool to help monitor training load, however, this could be utilized in conjunction with other metrics, such as the number of high intensity actions and accelerations performed, which are available within the GPS unit where the accelerometer is embedded. The GPS device where accelerometers are held can be easily attached and are simple to use and do not require a laboratory setting allowing greater practical application than fixed measures of ground reaction forces such as force platforms. During injury rehabilitation, the accelerometers can be potentially be utilized to identify changes in mechanical loading performance during a dance routine.

Despite KT being widely used within clinical practice, there is limited research on its impact on mechanical loading.[39,50] The current study does not support the notion that KT provides a positive reduction of PlayerLoad and, consequently, may not be advised as an intervention when the goal is to prevent injury from increased loads. Despite this, some dancers may choose to use KT for other proposed benefits including pain relief through its ability to lift the skin and facilitate blood and lymph flow.[49] Other factors include a small immediate increase in muscle strength,[62] improved muscle activity and alignment,[63] and increased range of motion,[63] each of which might have performance benefits. Some limitations existed within the study and a larger sample size is advocated in further investigation, and the results can only be generalized to the healthy dance population utilized.

Conclusion

Application of a KT corrective taping strategy produced no significant changes in measures of uniaxial and triaxial loading during the DAFT in healthy dancers, thus highlighting the need to potentially consider alternative injury reduction strategies in this population. The present study quantifies sensitivity of triaxial accelerometers at C7 and the LL allowing practitioners to detect PlayerLoad fluctuations during a dance-specific fatigue protocol, indicating increased loading with more complex movement patterns. Furthermore, greater levels of sensitivity and relative loading was discovered at the LL unit location suggesting that if inferences are to be determined regarding lower-limb kinematics, triaxial accelerometers may need to be applied at more distal locations than the traditional C7 unit placement. Real-time monitoring of PL metrics in addition to other GPS values, such as the number of high intensity actions during dance training, may be a useful strategy to recognize alterations in external load, thus allowing practitioners and coaches a non-invasive method of monitoring loading and variations in individual responses to practice and performance. This in turn could be subsequently used to provide a greater scientific approach to dance training periodization and monitoring of dancer health.

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