FORCE-VELOCITY PROFILES OF DANCERS AND ENDURANCE RUNNERS DURING ANKLE-SPECIFIC STRETCH-SHORTENING CYCLE TASKS

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While dance and endurance running drastically differ from one another in an anecdotal context, both modalities of movement necessitate proficient stretch-shortening cycle (SSC) function about the ankle-joint. The purpose of the present study was to compare force-velocity profiles in dancers (n=6) and endurance runners (n=6) during a countermovement hop (CMH) and 30 cm drop hop (DH30) to elucidate differences between groups that would potentially stimulate effective training regimens. Average relative force-time, velocity-time and force-velocity curves were generated for each group's CMH and DH30. Dancers hopped significantly higher ($p \leq 0.05$) than endurance runners in both hopping tasks. Data from this investigation indicate that dancers and runners have distinctive temporal patterns and force production characteristics during ankle-joint SSC tasks with respect to the eccentric and concentric phase. This may be due to the unique SSC characteristics of each group's corresponding training protocols.

KEYWORDS: hopping, power, performance

INTRODUCTION: Ankle-joint stretch-shortening cycle (SSC) action is a prominent factor of performance for several types of athletes. Dancers and endurance runners in particular rely a great deal on the ankle-joint, however, possess large variances in modality of utilization. For instance, dancers are required to plantarflex the ankle maximally upon take-off and be cognizant of the 'weight' in which they land with from a leap. Furthermore, dancers strive to achieve maximal center of displacement for most dance leaps and jumps. While endurance runners focus less on aesthetic appeal of the ankle, different foot striking techniques (i.e. forefoot, mid-foot, heel) are trained to optimize mechanical performance and metabolic conservation. A vertical component is, in fact, involved in endurance running, but the primary goal remains as minimal time-to-completion for a given horizontal distance. The distinguished ideals of both types of movement may be reflected in biomechanical measures of ankle-specific SSC tasks. This could include differences in the timing and magnitude of force production during the eccentric and concentric phases of a SSC. Peak force, impulse and peak power may illustrate a portion of ankle-joint function during an isolated movement. Such parameters are associated with center of mass displacement and potentially even predict performance (Rice, van Werkhoven, Merrit, et al., 2018). Average force-time, velocity-time and force-velocity curves have previously been generated to further identify variances in SSC capability between different populations (Rice, van Werkhoven, Merrit, et al., 2018; Cormie, McBride & McCauley, 2009). While both dancers and endurance runners employ cyclical ankle-joint SSC actions, training for competition largely contrasts between these groups. A comparison of hopping performance between these athletes may assist in delineating possible eccentric and concentric phase kinetic differences to provide a basis for strength and conditioning programs. The purpose of the present study was to compare force-velocity profiles in dancers and endurance runners during a countermovement hop (CMH) and 30 cm drop hop (DH30) to elucidate differences between groups that would potentially stimulate effective training regimens.

METHODS: Females between the ages of 18-25 years were recruited for the present investigation. Dancers (n = 6; age = 20.0 ± 1.3 years; 162.8 ± 6.2 cm; 58.6 ± 8.7 kg; years training = 14.3 ± 2.7 years) were required to have a minimum of 10 years of dance background in ballet, jazz, and/or modern/contemporary and be currently training three or more times per week. Endurance runners (n = 6; age = 20.3 ± 1.0 years; 166.4 ± 8.0 cm; 59.5 ± 7.6 kg; years training = 7.6 ± 1.9 years) were required to have a minimum of 5 years of running background and be currently running 10 miles or three times per week. All subjects were healthy with no lower limb musculoskeletal injury, fracture or neuromuscular disease within the past six months.

Subjects visited the laboratory one time for data collection. Upon arrival, all subjects signed an informed consent prior to completing the ACSM health-screening questionnaire. Height and weight was obtained from each subject prior to performing the stretch-shortening cycle tasks. A custom-designed sled equipped with dual force plates (Bertec, Columbus, OH, USA) and a potentiometer (Celesco, Chatsworth, CA, USA) was set at an incline of 10˚ for the countermovement hops (CMH) and 30 cm drop hops (DH30).

In order to isolate the ankle-joint, subjects laid flat on the sled with a strap tethered just proximal of the patella and a pad behind the knees to restrict movement. Subjects then performed the CMH. Subjects were instructed to rise onto the toes while an investigator counted down from three to maximally dorsiflex and then hop maximally by plantarflexing the ankles. Then, 30 cm was measured from the top of the sled carriage to mark where the individual would be lifted to by an investigator for the drop hop. An investigator would then lift the sled to the respective 30 cm, count to three and then release the sled. All subjects were instructed to hop as high as they could upon contact with the force plates. Three trials of each hop were completed and separated by two-minute rest periods each.

Hopping data were collected at a 1,000 Hz and analyzed with a custom-designed LabVIEW program (National Instruments, Version 8.2, Austin, TX). The CMH and DH30 trial with the greatest displacement was used for further analysis. Forward dynamics were used for determination of velocities from force plate data. Eccentric peak force and impulse as well as concentric peak force, impulse and peak power were determined from force-time and displacement-time curves during the CMH and DH30 trials. Integration of force and time was calculated for eccentric and concentric impulse and normalized to body mass to obtain relative impulse values. The highest eccentric force and concentric force and power during both hopping tasks were normalized to body mass for relative measures. Individual force-time, velocity-time and force-velocity curves were generated for each subject and re-sampled to 500 samples for each subject's CMH and DH30 as previously described (Rice, van Werkhoven, Merrit, et al., 2018). All extracted force-time curves were normalized to subjects' body masses. An average relative force-time, velocity-time and force-velocity curve was then generated for each group to further compare biomechanical SSC differences.

Statistical parametric mapping was performed for determination of significant differences during both hopping condition ensemble averages using a General Linear Model Univariate Analysis (Pataky, Robinson & Vanrenterghem, 2013). Statistical analyses were performed in SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) utilizing a Student's t-test for comparison of all variables between dancers and endurance runners. An *a priori* value of $p \leq 0.05$ was set for statistical significance.

RESULTS: No significant anthropometric differences existed between dancers and endurance runners. Dancers had significantly more years of training than did endurance runners ($p \leq 0.05$). During the countermovement hop (CMH), dancers hopped significantly higher than endurance runners as shown in Table 1. Dancers also had significantly greater relative concentric peak force and relative concentric peak power during the CMH than endurance runners, represented in Table 1. During the 30 cm drop hop (DH30), dancers hopped significantly higher than endurance runners as shown in Table 1. No other relative peak or impulse significant differences existed between dancers and endurance runners during the DH30. Average relative force-time and velocity-time curve significant differences of both hopping conditions are indicated by the areas shaded gray in Figure 1.

Table 1: Biomechanical variables during hopping tasks. Mean ± SD.

Hop Type	CMH		DH30	
Group	Dancers	Runners	Dancers	Runners
Hop Height (m)	0.19 ± 0.03*	0.14 ± 0.03	0.26 ± 0.04*	0.21 ± 0.03
Rel Ecc PF (N•kg^{-1})	15.92 ± 3.98	13.67 ± 2.48	26.40 ± 6.21	30.20 ± 10.27
Rel Ecc Imp (N•s•kg^{-1})	0.97 ± 0.25	1.13 ± 0.26	1.34 ± 0.21	1.35 ± 0.11
Rel Conc PF (N•kg^{-1})	17.97 ± 3.00*	14.28 ± 1.48	27.82 ± 6.37	25.45 ± 7.58
Rel Conc Imp (N•s•kg^{-1})	1.03 ± 0.14	1.04 ± 0.39	1.21 ± 0.23	1.17 ± 0.08
Rel Conc PP (W•kg^{-1})	10.62 ± 2.45*	6.85 ± 1.84	16.88 ± 4.48	14.18 ± 4.34

Note. Rel: Relative; Ecc: Eccentric; PF: Peak Force; Imp: Impulse; Conc: Concentric; PP: Peak Power.
* Significantly greater ($p \leq 0.05$) than Runners.

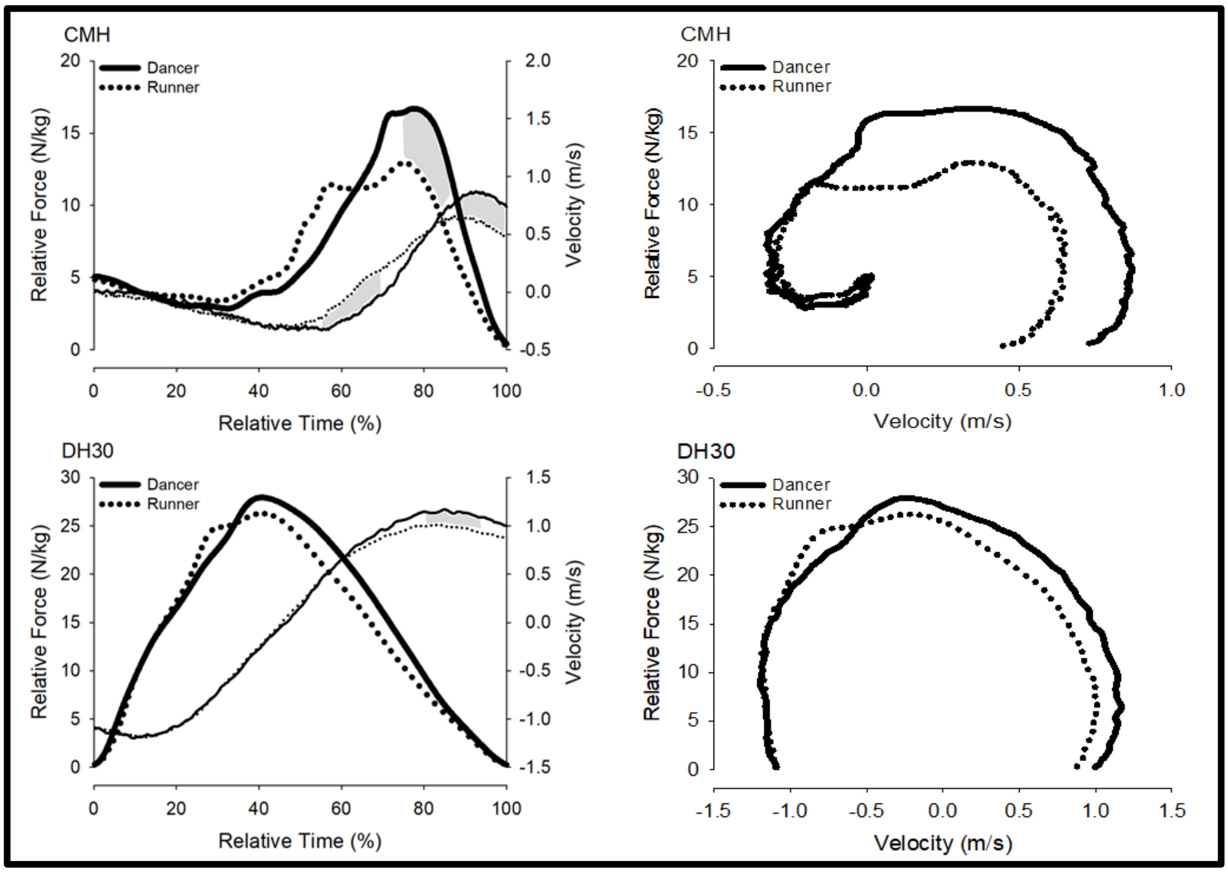

Figure 1: Average relative force-time, velocity-time and force-velocity curves during the countermovement hop and 30 cm drop hop tasks of dancers and endurance runners.

DISCUSSION: The SSC objective for dancers could arguably be to move through a maximal center of mass displacement with aesthetic appeal necessary for the visual performance. The SSC objective for endurance runners may be to optimize utilization of stored elastic energy to conserve energy, which does not necessitate maximizing vertical displacement as in dancing.

This could therefore indicate that there is an unequivocal eccentric-concentric phase kinetic pattern in each group. In dancers, there appeared to be a longer force development in the eccentric phase and a shorter and higher force production in the concentric phase. This pattern in endurance runners appeared to be rapid force development in the eccentric phase followed by a slightly longer and lower force production in the concentric phase. In order to optimize stored elastic energy in the tendon it is essential to maintain less than a 3% change in muscle length during the eccentric phase (Flitney & Hirst, 1978). Such muscle length maintenance requires a very rapid engagement of actomyosin cross-bridges during force output in the eccentric phase of an ankle SSC movement. This was observed in the countermovement hopping pattern of the endurance runners, in which a fast rise in rate of force development with a subsequent temporary decline in force with a second slowing force production phase prior to take-off (concentric) occurred, potentially for energy conservation. The requirement for a dance movement is not efficiency, but rather aesthetic appeal in which there is a more fluid and controlled build up to an explosive concentric action. A foot strike during running has been reported to be approximately 100-150 ms while a respective dance leap is 210-300 ms (Kulig, Fietzer & Popovich, 2011). Thus, it is not surprising that there were distinguished temporal patterns in the hopping tasks of each group. During the CMH, endurance runners spent approximately 65% of their time in the eccentric phase and dancers spent nearly 75% of their time in the eccentric phase. The drop hop patterns between the two groups, however, were more similar. This may be a result of the greater eccentric component involved in a drop hop versus a countermovement hop. With comparable volume of ankle-joint utilization, dancers and endurance runners may have discrete supplemental training needs. Future investigations seeking to identify the unique biomechanical characteristics of these athletes during hopping tasks should also implement novel training techniques to hone the ankle-joint SSC function of dancers and endurance runners.

CONCLUSION: This study compared force-velocity profiles of stretch-shortening cycle performance in two isolated ankle-joint tasks between dancers and endurance runners. The data indicate that there are unique eccentric and concentric phase kinetics to both athletic populations, which may be reflective of the modality in which they train. It appears that dancers are concerned greatly with hop height, while endurance runners may be more focused on energy conservation.

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