THE KNEE JOINT MOMENT AND POWER DURING BALLET'S SIMPLE GROUND ÉCHAPPÉ- COMPARISON OF DIFFERENTIAL PHYSICAL CONDITION IN DANCERS WITH AND WITHOUT KNEE PAIN

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The purpose of this study was to investigate the differential effect of physical condition on the impact force and the knee joint kinematics and kinetics of the dominant leg during ballet's simple ground échappé in ballet dancers with and without anterior knee pain. Ten Eagle cameras (200 Hz) and two AMTI force platforms (2000 Hz) were synchronized to collect the data. The study showed ballet dancers exerted greater knee extensor moment and power generation in hard physical condition than in easy condition during simple ground échappé. Moreover, ballet dancers with knee pain tended to protect their knees with greater knee power absorption during simple ground échappé compared to dancers without knee pain.

KEYWORDS: ballet dance, inverse dynamic, anterior knee pain.

INTRODUCTION: Ballet dance is physically demanding and includes many leaping, turning and balancing movements. A successful ballet performance involves movement continuity, rhythm, expressiveness, aesthetic positioning, dynamic versatility, and stage presence (Minden, 2005). Ballet dancers need strength, flexibility, balance abilities, and kinaesthetic awareness to accomplish such artistic movement (Minden, 2005). In the versatile practices of ballet, leaping is a highly skilled and intensive movement and often leads to the risk of injury. Ballet's simple ground échappé is quiet basic leaping practice. However, it is different from ordinary jumps such as counter movement jump. Ballet dancers have to land with hip turnout in order to achieve the classical dance posture. Such turnout at the hip joint could lead to so called "screwing the knees" which place considerable stress on the knee joint (Milan, 1994). Moreover, during repetitive leaping, the knee would sustain great stress. Over a long period of time, accumulated muscular fatigue may change their movement patterns. The anterior knee pain is a common syndrome among ballet dancers. Knee injuries account for 14-20% of all ballet injuries (Milan, 1994). The purpose of this study was to investigate the differential effect of physical condition on the impact force and the knee joint kinematics and kinetics of the dominant leg during ballet's simple ground échappé in ballet dancers with and without anterior knee pain. It was hypothesized that there would be difference found between dancers with and without anterior knee pain in different physical conditions.

METHOD: Seven female ballet dancers with anterior knee pain (age: 18.6 ± 0.5 years; height: 161.7 ± 2.9 cm; mass: 50.7 ± 4.2 kg) and seven ballet dancers without anterior knee pain (age: 18.1 ± 0.4 years; height: 158.4 ± 3.2 cm; mass: 50.9 ± 5.1 kg) voluntarily participated in this study. Subjects with or without anterior knee pain were estimated by a physical therapist according to Laprade (2002). Informed consent was obtained from all subjects. This study was approved by the Ethical Committee of the University. A warm-up of ten-minute stretching was performed prior to the testing protocol. Each subject performed ballet's simple ground échappé for twenty sets (Figure 1_a~e). The leaping pace was controlled by a metronome (75 times/minute). The rating of perceived exertion (RPE) was obtained after testing. The RPE of subjects with or without anterior knee pain were 14.3 ± 1.3 and 14.0 ± 1.0, respectively, in which the exertion level was between some hard and hard. Subjects' knee isometric contraction was also test on Biodex (Biodex Medical Systems, Inc. Shirley, NY, USA). The knee extension peak torque of subjects with and without anterior

knee pain was 3.2 ± 0.8 and 3.1 ± 0.9 Nm/kg. The knee flexion peak torque of subjects with and without anterior knee pain was 1.3 ± 0.2 and 1.4 ± 0.3 Nm/kg, respectively.
The movement data were collected with ten Eagle cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) at 200 Hz sampling rate which were positioned around the performance area. Reflective markers were placed in a modified Helen Hayes configuration to identify the segment motion. Cameras were synchronized to two force platforms (AMTI Inc., Watertown, MA, USA) which sampling rate was 2000 Hz. One platform collected the right leg data, and another collected the left leg data. Both kinematic and kinetic data were recorded in EVaRT software (Version 4.6, Motion Analysis Corporation, Santa Rosa, CA, USA).

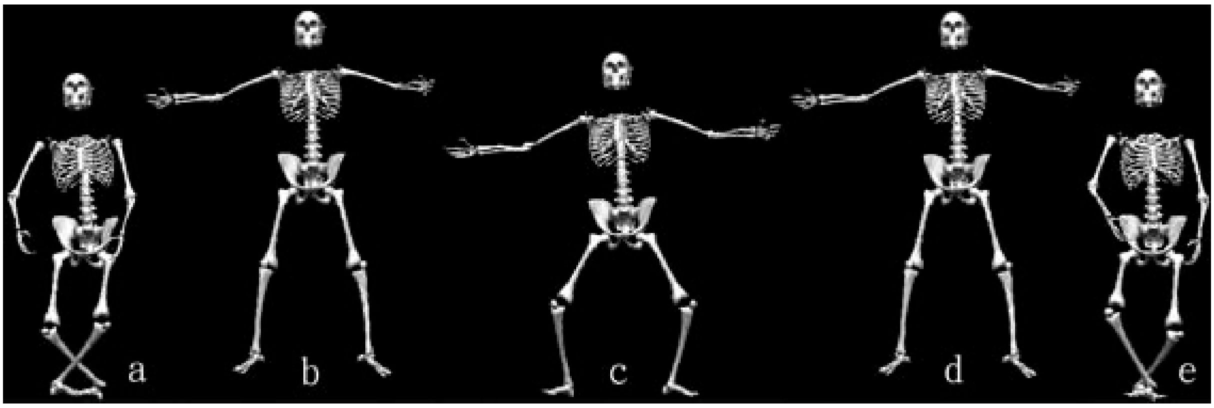

Figure 1. a~e: A set of the ballet's simple ground échappé.

The data were analyzed in The Monitor Monitor software (Version 8, Innovative Sports Training, Inc., Chicago, IL, USA). The dominant leg, determined in relation to the foot normally used to kick a ball, was analyzed for all subjects. In order to compare the easy and hard conditions of ballet's simple ground échappé, we defined the first and last three sets to refer to the easy and hard conditions, respectively. Subjects can only step on one force platform with one leg when splitting legs (Figure 1_c) in which contact phase was defined. During the contact phase, the knee joint kinetics was analyzed. The moment and power of knee joint was calculated from the inverse dynamics. The contact phase was then separated eccentric and concentric phases which determined using maximum knee flexion threshold. The contact phase, defined as the time from foot contact to take off from the ground, was analyzed. The instant of foot contact and take off during the contact phase was determined using a 30 N vertical ground reaction force (vGRF) threshold, respectively. Kinetic variables were normalized by each subject's body weight. Mix design two-way (2 groups × 2 conditions) ANOVAs was used to compare the differences between groups and conditions. The significance level was set at α=.05. The *post-hoc* analysis was performed with the Bonferroni test. The effect size was calculated on all variables.

RESULTS: All subjects had significantly greater peak net knee moment (P=.026) and peak power generation (P<.001) in easy condition than in hard condition. They took significantly longer time during the concentric phase (P=.003) and the total contact phase (P=.012) in hard condition than in easy condition (Table 1). There was no significant difference found between dancers with and without anterior knee pain in the rest of variables. The between-conditions effect sizes were shown in Table 2. Dancers without knee pain showed large effect size on eccentric time (effect size=1.08). The between-dancers effect sizes were shown in Table 3. The peak knee power absorption showed medium effect size between dancers with and without knee pain in both easy and hard condition (effect size=0.47 and 0.52, respectively). The peak knee moment showed large effect size between dancers with and without knee pain in hard condition (effect size=1.03). There were medium effect size on eccentric time in easy condition (effect size=0.46) and large effect size on concentric time in hard condition (effect size=0.86).

Table 1. Knee joint kinetics and kinematics of the dominant leg during first contact phase.

		Easy Condition	Hard Condition
Without Knee Pain	Peak vGRF (BW)	1.38 ± 0.13	1.39 ± 0.28
	Peak KneeMom (Nm/kg)	1.57 ± 0.21	1.39 ± 0.12 *
	Peak KneePowAbs (W/kg)	6.79 ± 2.07	7.10 ± 1.50
	Peak KneePowGen (W/kg)	6.49 ± 1.32	4.48 ± 0.99 *
	Peak KneeFlexAng (deg)	83.10 ± 7.75	82.16 ± 7.84
	KneeFlexAngCONT (deg)	16.41 ± 7.60	15.56 ± 6.72
	TimeEcc (ms)	235 ± 12	261 ± 32
	TimeCon (ms)	243 ± 11	303 ± 64 *
	TimeCONT (ms)	479 ± 14	565 ± 87 *
With Knee Pain	Peak vGRFMax (BW)	1.53 ± 0.24	1.47 ± 0.26
	Peak KneeMom (Nm/kg)	1.65 ± 0.26	1.56 ± 0.20 *
	Peak KneePowAbs (W/kg)	7.77 ± 2.07	7.91 ± 1.64
	Peak KneePowGen (W/kg)	6.61 ± 1.76	4.85 ±1.06 *
	Peak KneeFlexAng (deg)	83.23 ± 7.08	83.03 ± 4.66
	KneeFlexAngCONT (deg)	14.78 ± 3.83	16.17 ± 2.41
	TimeEcc (ms)	247 ± 35	268 ± 61
	TimeCon (ms)	239 ± 35	261 ± 25 *
	TimeCONT (ms)	488 ± 69	530 ± 78 *

* Significance found between easy and hard condition. KneeMom=Knee moment; KneePowAbs= Knee power absorption; KneePowGen= Knee power generation; KneeFlexAng=Knee flexion angle; KneeFlexAngCONT=Knee flexion angle at contact; TimeEcc=Time of eccentric phase; TimeCon= Time of concentric phase; TimeCONT=Time of total contact phase.

Table 2. Effect Size between easy and hard conditions

	Without Knee Pain	With Knee Pain
Peak vGRFMax (BW)	0.05	0.24
Peak KneeMom (Nm/kg)	1.05 *	0.39
Peak KneePowAbs (W/kg)	0.17	0.07
Peak KneePowGen (W/kg)	1.72 *	1.21 *
Peak KneeFlexAng (deg)	0.12	0.03
KneeFlexAngCONT (deg)	0.12	0.43
TimeEcc (ms)	1.08 *	0.42
TimeCon (ms)	1.31 *	0.72 *
TimeCONT (ms)	1.38 *	0.57 *

* Medium to large effect size.

Table 3. Effect size between dancers with and without knee pain.

	Easy Condition	Hard Condition
Peak vGRF (BW)	0.78 *	0.30
Peak KneeMom (Nm/kg)	0.34	1.03 *
Peak KneePowAbs (W/kg)	0.47 *	0.52 *
Peak KneePowGen (W/kg)	0.08	0.36
Peak KneeFlexAng (deg)	0.02	0.13
KneeFlexAngCONT (deg)	0.27	0.12
TimeEcc (ms)	0.46 *	0.14
TimeCon (ms)	0.15	0.86 *
TimeCONT (ms)	0.18	0.42

* Medium to large effect size.

DISCUSSION: The purpose of this study was to compare the differential physical condition during ballet's simple ground échappé in ballet dancers with and without anterior knee pain. Major findings indicated that ballet dancers exerted greater knee extensor moment and power generation in hard physical condition during simple ground échappé. The repetitive leaping made ballet dancers feel hard to keep up the rhythm and aesthetic positioning. Therefore, more knee extensors effort had been elicited to accomplish the movement.

Ballet dancers spent more time on ground contact and concentric movement in the hard physical condition. Maybe they were trying to generate more effort from ground reaction force and exertion powers from the knee extensor muscles for jumping off. On the other hand, ballet dancers also spent more time on eccentric movement during landing in hard physical condition. We suggested that they can get more power absorption from knee extensor muscles to decelerate the body during landing.

In the study, we did not find any statistical difference between ballet dancers with and without anterior knee pain. However, there were some rather great mean differences observed with medium to large effect size. Dancers with knee pain landed with greater power absorption from the knee joint than dancers without knee pain. Also, dancers with knee pain had greater knee extensor moment than dancer without knee pain in hard physical condition. Furthermore, they spent more time on eccentric movement than dancers without knee pain in easy physical condition. Combining the aforementioned evidence, we suggested that ballet dancers with knee pain tended to protect their knees with greater knee power absorption during simple ground échappé compared to dancers without knee pain.

In this study, no difference was found on knee joint positions. This meant that differential physical condition or knee pain did not affect the outcome performance on landing during simple ground échappé. Even dancers had knee pain or in hard physical condition; they can still maintain the adequate body positioning to achieve the requirement of aesthetic position in ballet dance. However, the changes on internal knee execution pattern had been found.

Further investigations into the muscular activities would guarantee the internal interpretation of the neuromuscular performance of knee joint muscles during simple ground échappé. Although only a few variables showed statistical difference in this study, some variables showed medium to large effect size. The insignificant findings may be due to the low subject number. Recruiting more subjects is guaranteed to further study.

CONCLUSION: This study explored the effect of physical condition in ballet dancers with and without anterior knee pain. Ballet dancers exerted greater knee extensor moment and power generation in hard physical condition during simple ground échappé. Ballet dancers with knee pain tended to protect their knees with greater knee power absorption during simple ground échappé compared to dancers without knee pain. Strengthening ballet dancers' knee extensors was advocated to be a part of training program.

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