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POSTURAL CONTROL OF BALLET POSES

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Abstract

Half toe standing is an important posture to maintain in ballet. Investigation of the coupling effect between the individual feet of half toe standing posture should provide further guidance for understanding movement control in ballet. In this study, two force platforms were synchronized so as to investigate the amount of variability and the coupling effect of the COP left, COP right, COP net in different ballet poses. Fourteen young female adult college ballet dancers, 11 recreational runners, and 10 non-exercisers participated in the study. The five ballet postures investigated were: parallel position in flat foot (hip width distance), ballet first position (heel to heel) in flat foot, ballet first position in half toe-standing, ballet second position (separate two times hip-width distance) in half toe standing, and ballet second position in half toe standing posture. Three 30 s trials were collected for each participant in each condition. Quantification of the variability of COP_L and COP_R trajectories and their relation with COP_{net} was conducted by analysis of the standard deviation, approximate entropy (ApEn), and cross-approximate entropy (cross-ApEn). In the COP_R, COP_L in medial-lateral direction, the non-exerciser group had the lowest amount of variability compared to the college ballet dancers and the recreational runners. The SDs of COP_L, COP_R and COP_{net} were significantly ($p<0.05$) influenced by ballet posture. Moreover, the pattern of SDs for AP and ML motion on each COP variable was different. ApEn and cross-ApEn of COP net in the AP direction, and COP_L and COP_R in ML and AP revealed greater irregularity in the coupling of the half toe standing posture. There were no differences between groups except for SD of the individual foot in ML directions. Previous studies have shown that ballet dancers are qualitatively, but not quantitatively different in postural control than non ballet dancers. However, our finding did not support this hypothesis. One possible explanation for our failure to

support this may be due to the testing of a less experienced ballet dancer than tested in other studies.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

Postural Control of Ballet Poses

Introduction

Postural control is fundamentally concerned about body alignment and balance, and the resultant motion of the center of pressure and body sway (Massion, 1994; Rothwell, 1994, Winter, Prince, Frank, Powell & Zabjek, 1996). Many studies have conducted balance tests of postural control (Goldie, Bach & Evans, 1989; Murray, Seirewg, & Sepic, 1975), including of ballet dancers (Crotts, Thompson, Nahom, Ryan, & Newton, 1996; Golomer, Dupui, & Monod, 1997a, b). It is well established that balance control and body sway are affected by the presence and absence of visual information (Collins & DeLuca, 1993; Woollacott, Debu, & Mowatt, 1987).

Ballet dancers often practice ballet in front of a mirror, to adjust their posture, supporting the view that visual information is a key factor to maintain correct posture (Golomer & Dupi, 2000; Golomer, Dupui, & Monod, 1997a, b; Hugel, Cadopi, Kohler, & Perrin, 1999). Most studies of standing posture in ballet poses have used the single leg stance or change the standing conditions, such as with a foam surface or rigid surface (Schmit, Regis & Riley, 2005). However, there have been few studies that have tested ballet dancers with half toe standing that in ballet terms is defined as the demipointe position. Ballet dancers perform many postures in the demipointe position often trying to maintain balance for long periods of time.

Ballet students typically learn from the beginning to dance on demipointe wearing normal ballet shoes as instructors will often not let beginner dancers wear the pointe shoes. Once dancers have practiced for a long time and the skill is mature instructors will typically let the dancer wear point shoes. The outcome is that dancers are accustomed to dance in the normal ballet shoes, but use demipointe methods for advanced training of their balance skill.

In ballet, the most commonly used postures in demipoint are what are called first place, second place, and fifth place. It is important to maintain stability in each of these three poses in ballet as in all postures. Stability is often indexed by the amount of postural sway. However, postural sway can be traced to several factors, including in dancers to ankle sprain (Leanderson, 1996). The fifth place pose, is the most difficult and an unfamiliar position to an untrained participant, so often just the first place, second place, parallel and single leg standing posture are used to test the ballet posture of dancers. A previous study found that ballet dancers had better balance during the single leg posture compared to soccer players (Gerbino, 2007).

Only a few studies have examined half-toe standing and most focus on upper neuron pathology (Nolan & Kerrigan, 2002). Center of pressure (COP) variability is a key variable reflecting balance, so that as the amount of COP motion variability becomes larger it is interpreted that the stability decreases and body sway increases. Since dancers control their COP carefully, and use the COP to help them move easily, it is assumed that dance training leads to less COP movement variability than the untrained subject (Gerbino, 2007).

In this study, we will use two force platforms to measure each leg's contribution to the net COP (Winter, 1993). The goal was to compare the amount and structure of the variability of COP of the demipointe in different postures between young adult women in independent groups who are experienced college ballet dancers, recreational runners and non-exercisers. The experiment was set-up to test the hypothesis that ballet training leads to a reduced amount, but increased structure of variability of postural motion as indexed by COP.

Chapter 2

Methods

Participants

Thirty-five healthy young adult participants were recruited from the Pennsylvania State University. All subjects were female. The participants were 14 college ballet dancers, 11 recreational runners, and 10 non-exercisers. The participant's ages ranged from 18-25 years. The ballet dancers mean age and dance experiences were 19.9 years and 14.75 years, respectively. The recreational runner at least 1 year running experiences. The Institutional Review Board of the Pennsylvania State University approved the test protocol. All participants signed an approved informed consent form before beginning testing procedures.

Apparatus

Two Advanced Mechanical Technology, Inc (AMTI) force platforms were used to measure the ground reaction forces and torques and derive the center of pressure during the standing postures. Each force platform was connected to a personal computer for data acquisition. The platform records the media-lateral force (Fx), the antero-posterior force (Fy), vertical force (Fz), and the respective moments Mx, My, and Mz. The signals were amplified using a six-channel AMTI-Model (OR6-5-1000) amplifier. An amplifier gain of 4000 was used with a low-pass filter of 10 Hz, and the platform excitation voltage was set to 10 V. The data were collected at a sample frequency of 50 Hz. The data were down sampled to 25 Hz and filtered with a 10 Hz 2^{nd} order Butterworth low-pass filter.

Tasks and procedures

Five different postures were tested (see Figure 1). These were: a) parallel position in flat foot (hip width distance); b) ballet first position (heel to heel) in flat foot; c) ballet first position in half toe-standing; d) ballet second position (separate two times hip-width distance) in half toe standing; e) and ballet second position in half toe standing posture.

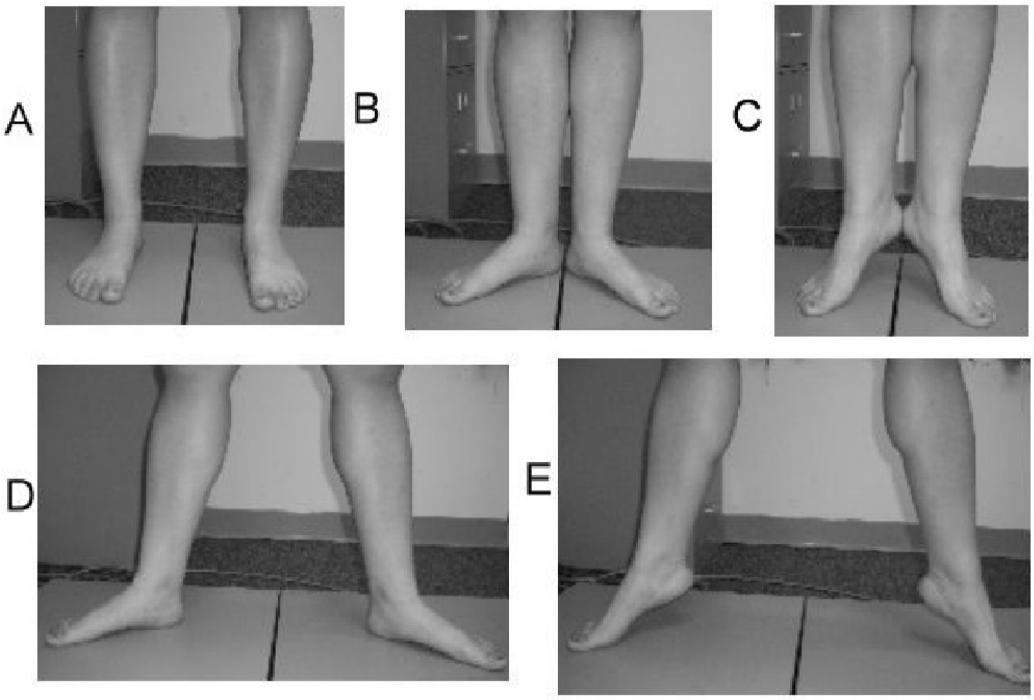

Fig.1: The 5 different ballet postures used in the experiment.

Participants performed 3, 30 s trials in each of the five ballet postures. The order of the testing of each posture was randomly determined for each participant. The non-exercise and recreational runner groups were instructed in the 5 ballet postures, excluding the parallel quiet standing position. Other positions of the foot posture angle will be to turn out as much as possible, and in those postures the participant can stand stable and maintain balance. The participants could use arm and hand motion as needed to maintain balance and dancers were also allowed to use the ballet basic hand posture to maintain balance.

Data analysis

The center of pressure is the location on the surface of support of the ground reaction vector (Winter et al., 1996). The center of pressure data were analyzed in both the x and y directions. The center of pressure was analyzed to reflect both the degree and structure of the variation of motion in the different postures as a function of group.

The analysis compared several dependent variables of postural motion as a function of the population group. The dependent variables were standard deviation, approximate entropy (ApEn), and cross ApEn (with m=2, r=0.2). The COP net was calculated from the COP of each platform by Winter's equation (1993).

ApEn reveals the regularity of a time series (Pincus, 1991). The values of ApEn are usually between 0 to 2, the lower value indicates high regularity, and the higher value which is near 2 indicates high irregularity. The coupling between two force platforms was determined by Cross ApEn. A higher Cross ApEn indicates weaker coupling between the COP left foot (force platform 1) and COP right foot (force platform 2) and a lower value indicates stronger coupling.

Chapter 3

Results

COP variability (SD)

Figure 2 shows an example of the trajectory variability for COP_L, COP_R and COP_{net} for a single trial of a ballet dancer in parallel position in flat foot. Left and right platform in the legend designate COP of the left and right feet, respectively.

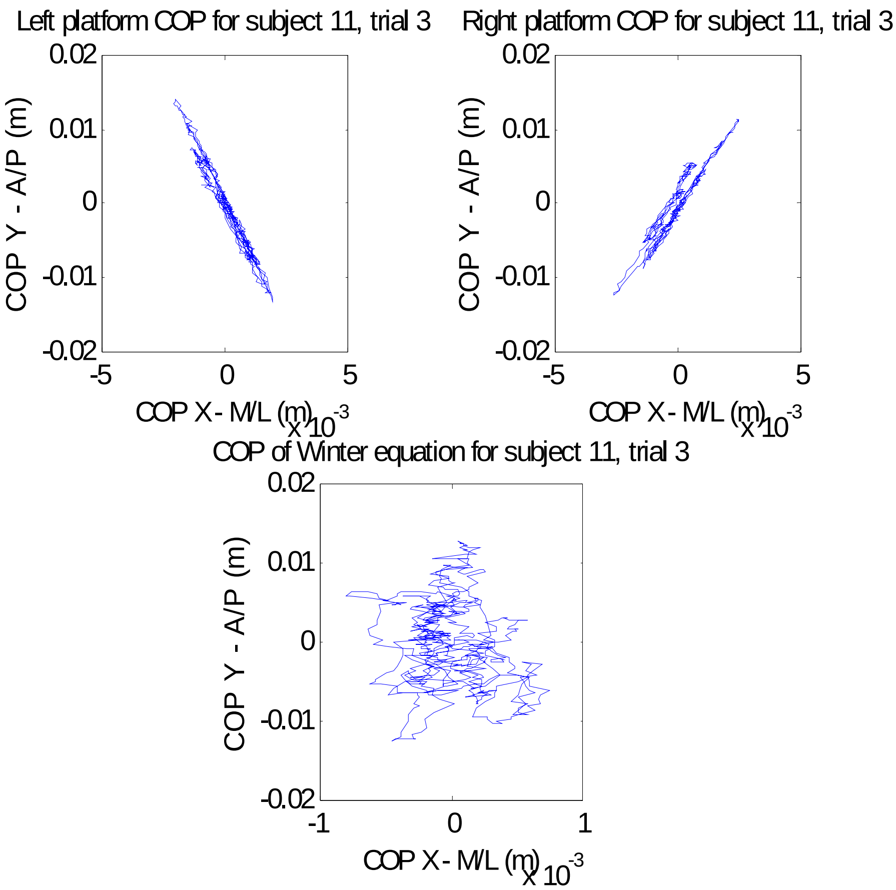

Fig. 2 Example of the trajectory variability for COP_L, COP_R and COP_{net} of ballet dancer

Medial-Lateral COP_{net}

The effect of posture on the SD in the medial-lateral direction COP_{net} was significant, $F(4,128) = 101.046$, $p < 0.05$. The highest variability was the posture with ballet first position in half toe-standing. The posture with the lowest variability was the parallel position in flat foot position. The pairwise comparison showed the ballet first position in flat foot was significantly higher than the parallel position, the ballet second position in flat foot, and the ballet second position in half toe standing. The ballet first position was significantly higher than the parallel position, the ballet first position in flat foot, the ballet second position in flat foot and the ballet second position in half toe standing. The ballet second position in flat foot was significantly higher than the parallel position and the ballet second position in half toe standing. The pattern of COP_{net} variability as a function of posture was similar of each group (Figure 2). The between groups effect of the SD medial-lateral COP_{net} direction was not significant, $F(2, 32) = 0.878$, $p > 0.05$.

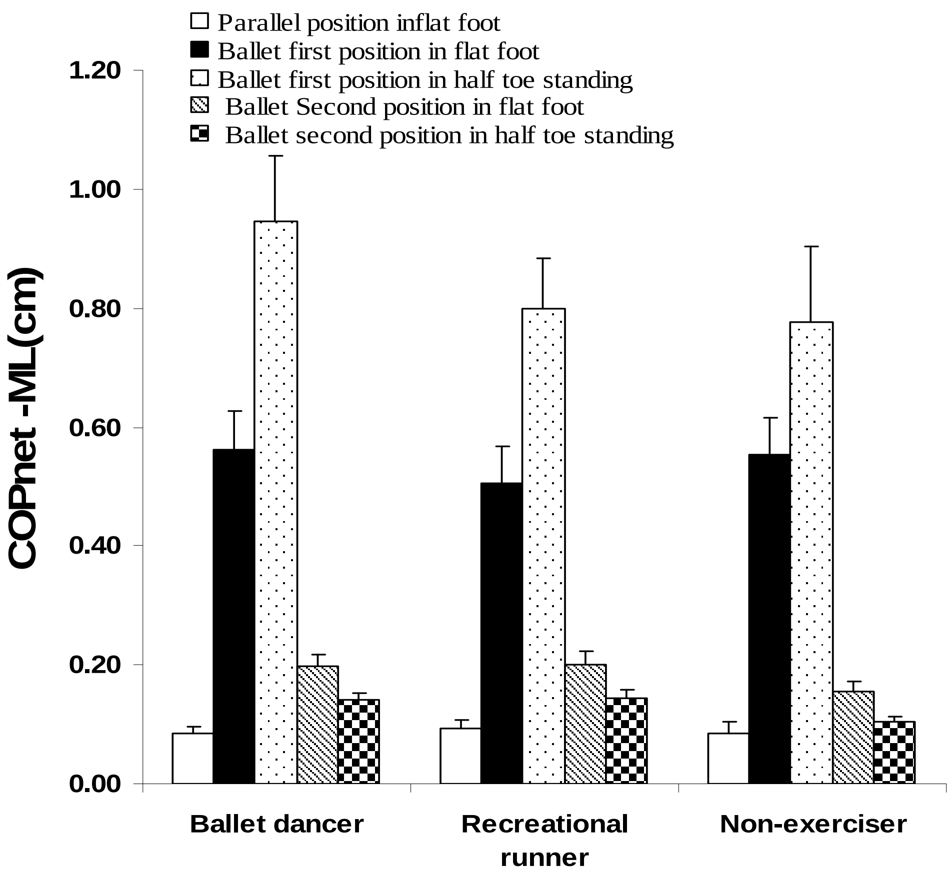

Fig. 2: Mean (SD) COP_{net} - ML as a function of group and posture.

Anterior-Posterior COP_{net}

In the anterior-posterior direction of COP_{net}, the posture effect for SD was significant, $F(4,128) = 34.846$, $p < 0.05$. The general pattern of SD for the postures in AP was different from that in the ML direction (Figure 3). The highest variability was in the posture with ballet first position in half toe-standing. The posture with the lowest variability was parallel position in flat foot position. The pairwise comparison showed that the parallel position was significantly higher than the ballet first position in flat foot, the ballet first position in half toe standing, the ballet second position in flat foot and the ballet second position in half toe standing. The ballet first position in flat foot was significantly higher than the ballet second position in half toe standing. The ballet first position in half toe standing was higher than the ballet first position in flat foot and the ballet second position in half toe standing. The ballet second position in flat foot was higher than the ballet first position in flat foot, the ballet first position in half toe standing, the ballet second position in half toe standing. The between groups effect of the SD anterior-posterior COP_{net} was not significant, $F (2, 32) = 1.695$ $p > 0.05$.

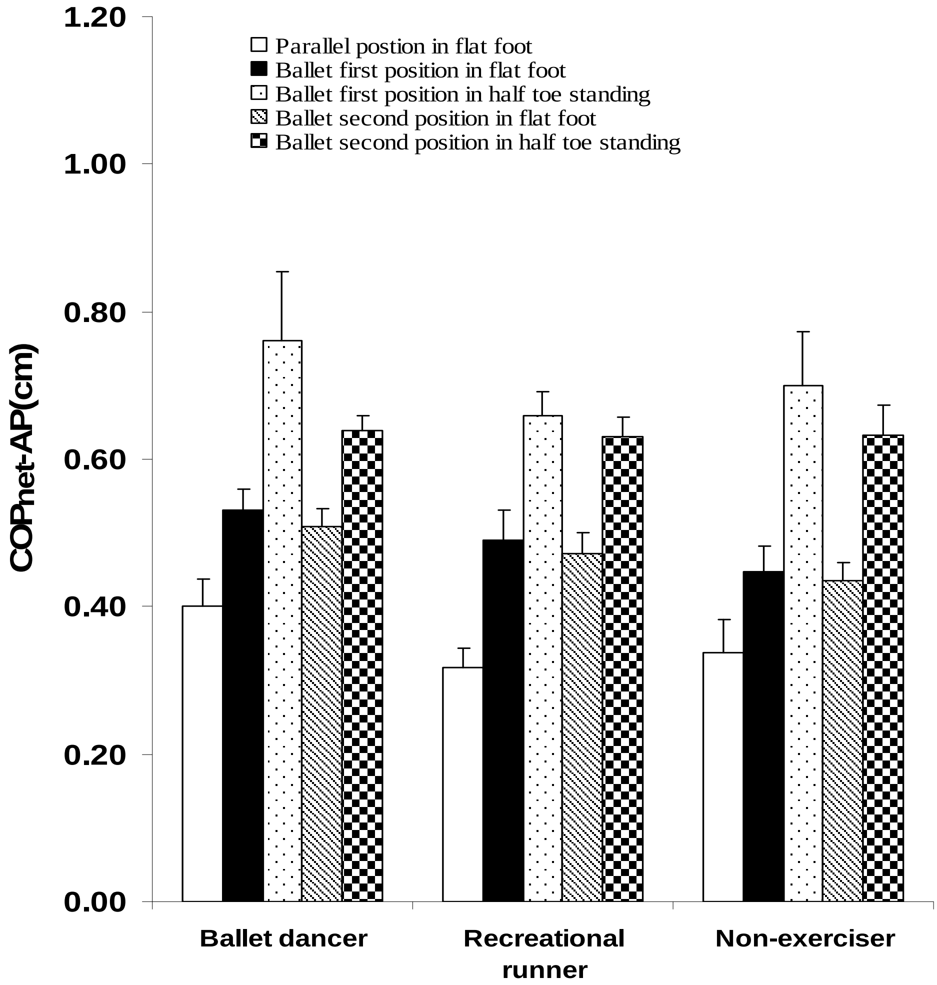

Fig. 3: Mean (SD) COP_{net} - AP as a function of group and posture.

Medial-Lateral direction COP_L

For the COP_L in the medial-lateral direction the SD of the within-subject posture effect was significant, $F(2,128) = 156.329$, $p < 0.05$ (Figure 4). The highest variability was the posture with ballet second position in half toe standing. The posture with the lowest variability was the parallel position in flat foot. The pairwise comparisons showed the ballet first position in flat foot was significantly higher than the parallel position, the ballet first position in half toe standing, and the ballet second position in half toe standing. The ballet first position in half toe standing was significantly higher than the parallel position, and the ballet second position in half toe standing. The ballet second position in flat foot was significantly higher than the parallel position, the ballet first position in half toe standing, and the ballet second position in half toe standing. The ballet second position in half toe standing was significantly higher than the parallel position. The between groups of left foot medial-lateral direction effect was significant $F(2, 32) = 7.343$, $p < 0.05$. The post hoc showed the ballet dancer was significantly higher than the non-exercisers. The SD COP_L in the medial-lateral direction of ballet dancers and recreational runner was not significantly different; the group with the lowest SD was the non-exerciser. In general, the pattern of COP_L-ML variability as a function of group and posture was different than that for AP.

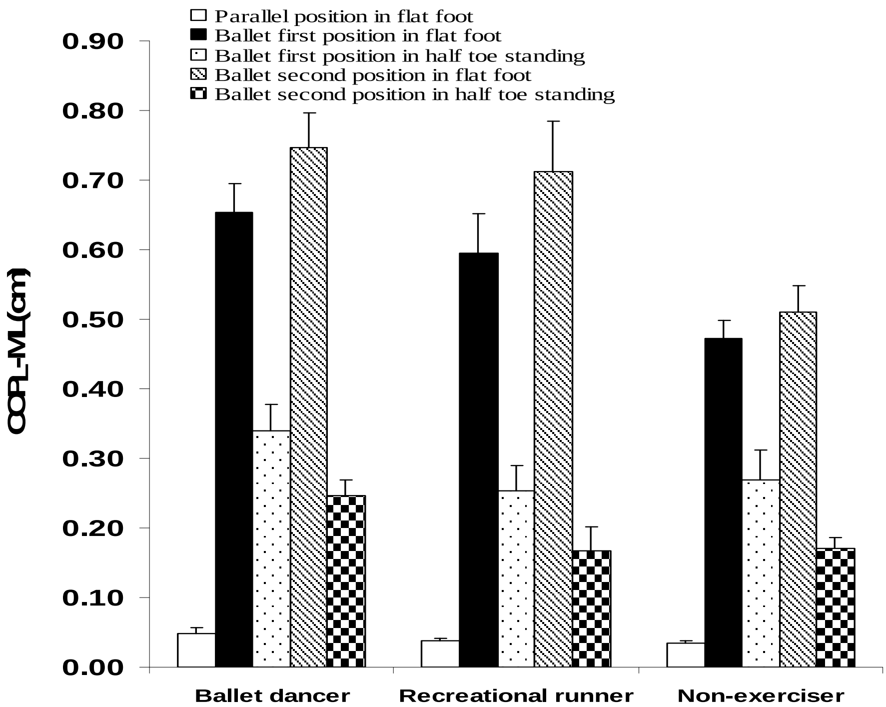

Fig.4**:** mean (SD) COP_L - ML as a function of group and posture.

Anterior-Posterior direction COP_L

For the COP_L in the anterior-posterior direction of the SD within-subject posture effect was significant, F (4,128) =45.389, $p < 0.05$ (Figure 5). The highest variability was the posture with ballet first position in half toe standing and ballet second position in half toe standing. The posture with the lowest variability was the parallel position in flat foot. The pariwise comparisons showed that the ballet first position in flat foot was significantly higher than the parallel position. The ballet first position in half toe standing and the ballet second position in half toe standing were higher than the parallel position, the ballet first position in half toe standing, the ballet second position in flat foot. The ballet second position in flat foot was significantly higher than the parallel position.

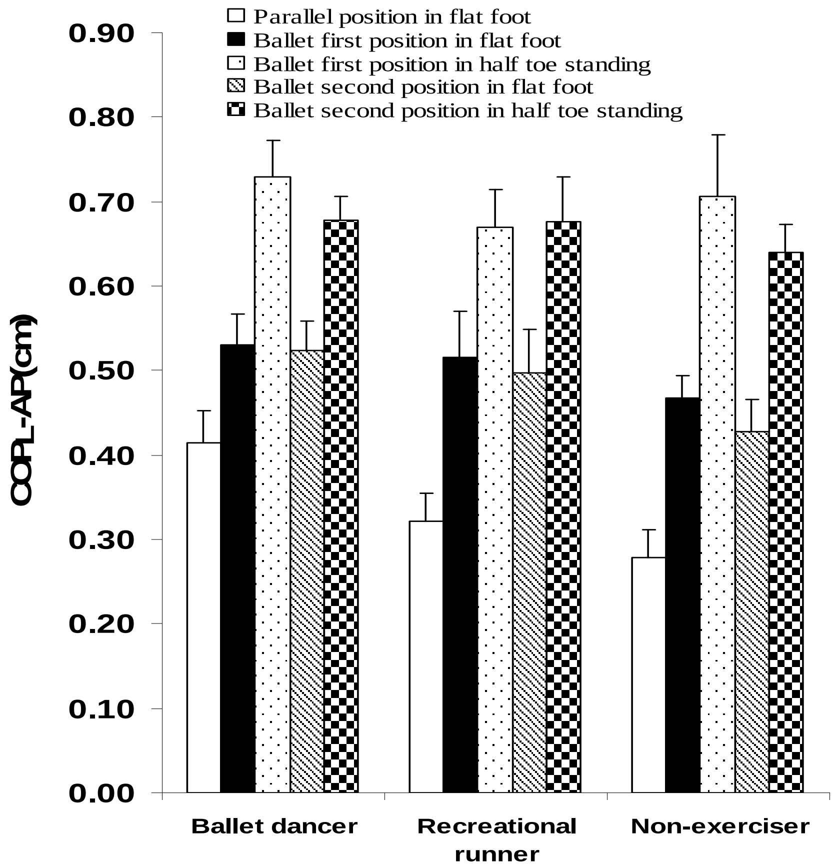

Fig.5: Mean (SD) COP_L - AP as a function of group and posture.

Medial-Lateral direction COP_R

The COP_R in the medial-lateral direction of the within-subject posture effect was significant, $F(4, 128) = 140.549$, $p < 0.05$ (Figure 6). The highest variability was the posture with the ballet second position in half toe standing. The posture with the lowest variability was the parallel position in flat foot. The pairwise comparisons showed that the result of the ballet first position in flat foot was significantly higher than the parallel position, the ballet first position in half toe standing, and the ballet second position in half toe standing. The ballet first position in half toe standing was significantly higher than the parallel position and the ballet second position in half toe standing. The ballet second position in flat foot was significantly higher than the parallel position, the ballet first position in flat foot, the ballet first position in half toe standing, and the ballet second position in half toe standing. The ballet second position in half toe standing was higher than the parallel position. The between groups effect of SD of COP_R was significant, $F (2, 32) = 4.797$, $p < 0.05$. The post hoc showed the ballet dancer was significantly higher than the non-exercisers. The ballet dancer group had the highest SD averaged across group in COP_R medial-lateral direction. The pattern of SD in the COP_R in medial-lateral direction as a function of posture was similar for each group.

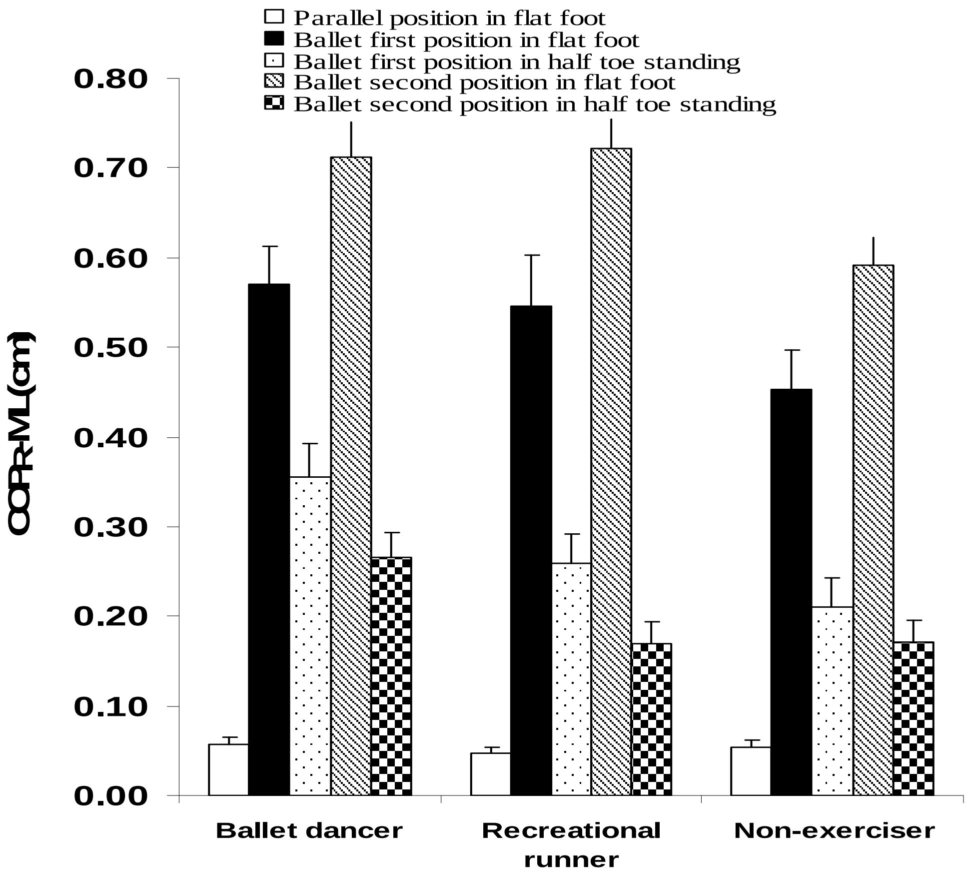

Fig.6: Mean (SD) COP_R - ML as a function of group and posture.

Anterior-Posterior direction COP_R

The COP_R in anterior-posterior direction of the within-subject posture effect was significant, $F (4, 128) = 29.069$, $p < 0.05$ (Figure 7). The highest variability was in the posture with the ballet first position in half toe standing. The posture with the lowest variability was the parallel position in flat foot. The pairwise comparisons showed that the ballet first position in flat foot was significantly higher than the parallel position. The ballet first position in half toe standing was significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position in flat foot. The ballet second position in half toe standing was significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position in flat foot. The between groups effect of the SD of COP_R in the anterior-posterior direction was not significant, $F (2, 32) = 0.803$ $p > 0.05$.

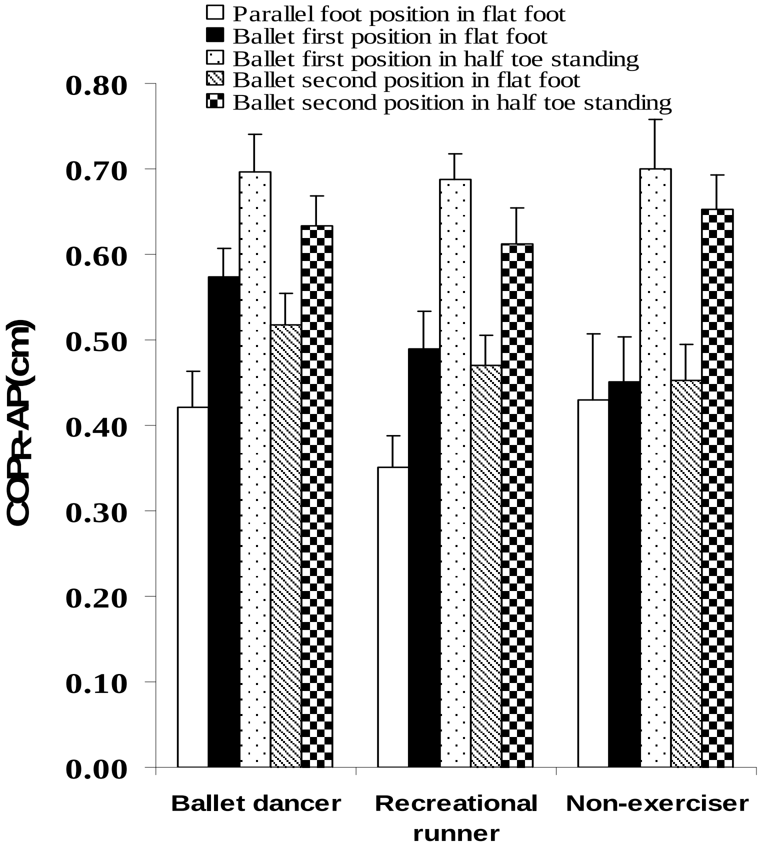

Fig.7: Mean (SD) COP_R - AP s a function of group and posture.

Medial-Lateral ApEn of COP_{net}

The ApEn of COP_{net} in medial-lateral direction of the within-subject posture effect was significant, $F(4, 128) = 89.678$, $p < 0.05$ (Figure 8). The highest irregularity was in the posture with the ballet second position in half toe standing. The posture with the lowest irregularity was the ballet first position. The pairwise comparisons showed the parallel position was significantly higher than the ballet first position in flat foot, the ballet first position in half toe standing, the ballet second position in flat foot. The ballet first position in half toe standing was significantly higher than the ballet first position in flat foot. The ballet second position in flat foot was significantly higher than ballet first position in flat foot. The ballet second position in half toe standing was significantly higher than the parallel position, the ballet second position in half toe standing, the ballet first position in flat foot, the ballet first position in half toe standing, and the ballet second position in flat foot. The between groups effect on ApEn of COP_{net} in the medial-lateral direction was not significant, $F(2, 32) = 1.706$, $p > 0.05$.

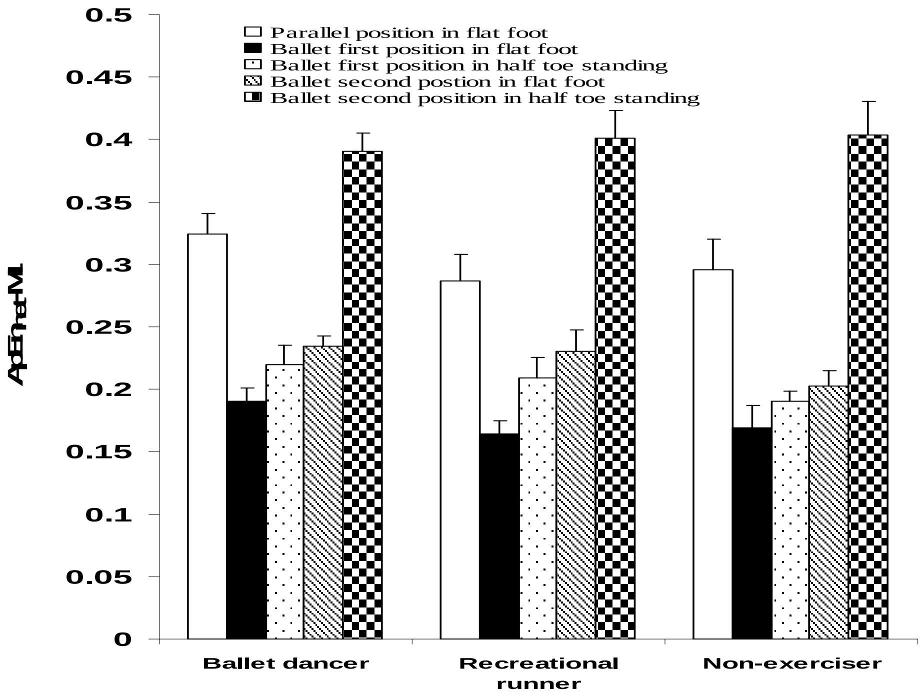

Fig.8:ApEn of COP_{net} - ML as a function of group and posture.

Anterior-Posterior ApEn of COP_{net}

The ApEn of COP_{net} in anterior-posterior direction of the within-subject posture effect was significant, $F(4, 128) = 82.55$, $p < 0.05$ (Figure 9). The highest irregularity was in the posture with the ballet second position in half toe standing. The posture with the lowest irregularity was the ballet first position. The pairwise comparisons showed the ballet first position in half toe standing was significantly higher than the parallel position, the ballet first position in flat foot, the ballet second position in flat foot. The ballet second position in flat foot was significantly higher than the parallel position and the ballet first position in flat foot. The ballet second position in half toe standing was significantly higher than the parallel position, the ballet first position in flat foot, the ballet first position in half toe standing, the ballet second position in flat foot. The between groups effect on ApEn of COP_{net} in the anterior-posterior direction was not significant, $F(2, 32) = 0.051$, $p > 0.05$.

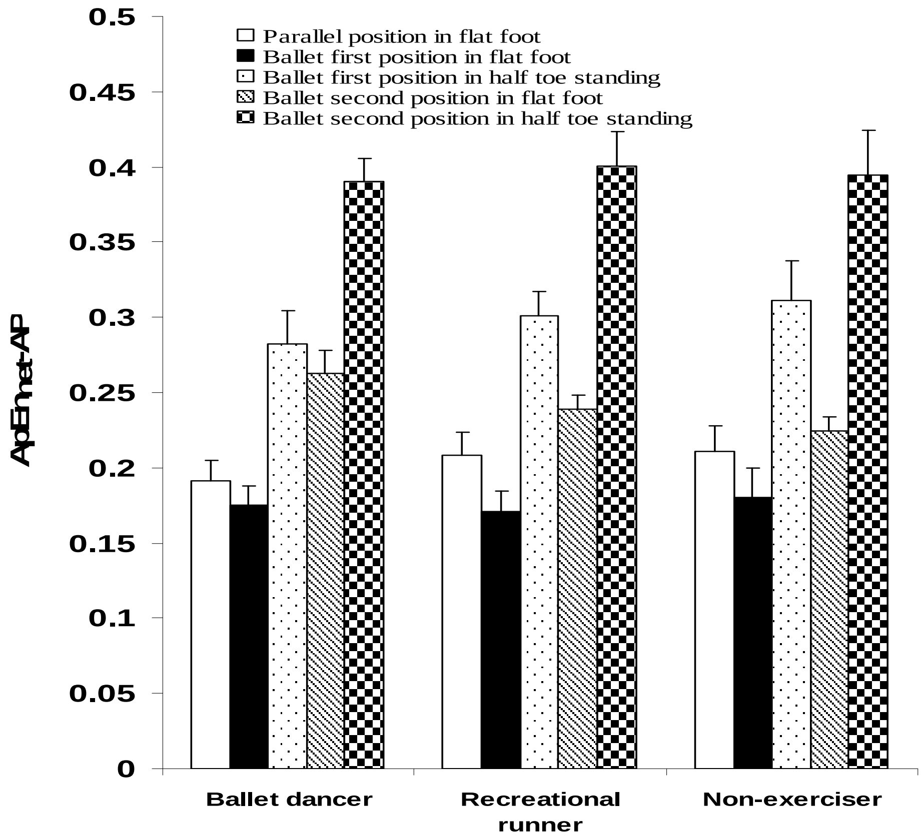

Fig.9: ApEn of COP_{net} - AP as a function of group and posture.

Medial-Lateral direction ApEn COP_L

The ApEn COP_L of in medial-lateral direction of the within-subject posture effect was significant, $F(4, 128) = 62.74$, $p < 0.05$ (Figure 10). The highest irregularity were in the posture with the ballet first position in half toe standing and ballet second position in half toe standing. The pairwise comparisons showed the ballet first position in half toe standing and ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, the ballet second position in flat foot. The ballet second position was significantly higher than the ballet first position in flat foot. The posture with the lowest irregularity was the parallel position in flat foot. The between groups effect on ApEn of COP_L in the medial-lateral direction was not significant, $F (2, 32) = 0.248$, $p > 0.05$.

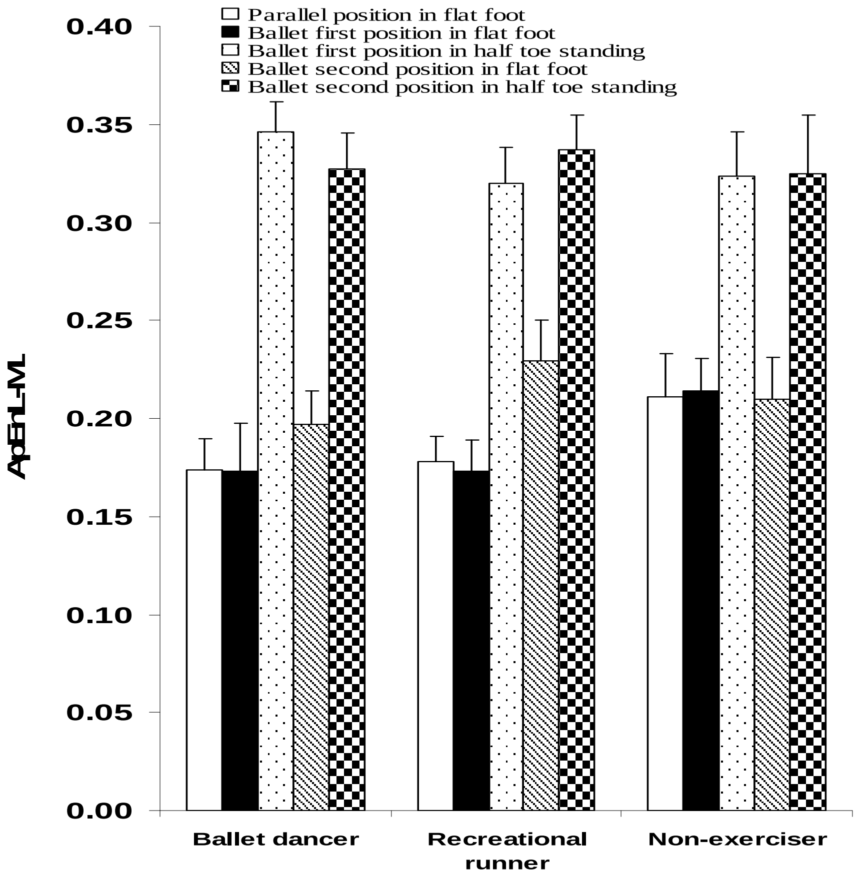

Fig.10: ApEn of COP_L - ML as a function of group and posture.

Anterior-Posterior ApEn of COP_L

The ApEn of COP_L in anterior-posterior direction of the within-subject posture effect was significant, $F (4, 128) = 125.586$, $p < 0.05$ (Figure 11). The highest irregularity was in the posture with the ballet first position in half toe standing. The posture with the lowest irregularity was the parallel position in flat foot. The pairwise comparisons showed the ballet first poison in half toe standing and the ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, the ballet second position in flat foot. The ballet second position in flat foot was significant higher than the parallel position. The between groups effect on ApEn of COP_L in the anterior-posterior direction was not significant, $F(2, 32) = 0.272$, $p > 0.05$.

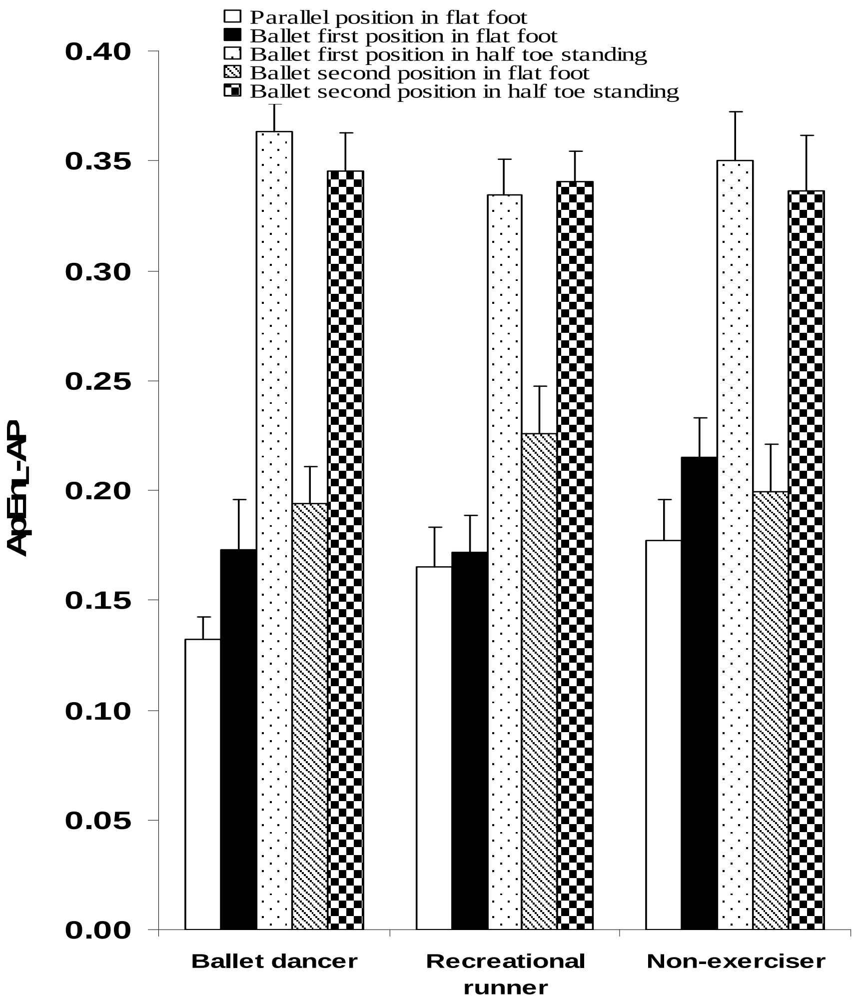

Fig.11: ApEn of COP_L - AP as a function of group and posture.

Media-Lateral ApEn of COP_R

The ApEn of COP_R in medial-lateral direction of the within-subject posture effect was significant, $F (4, 128) = 37.71$, $p < 0.05$ (Figure 12). The highest irregularity was in the posture with the ballet second position in half toe standing. The posture with the lowest irregularity was the parallel position in flat foot. The pairwise comparisons showed the ballet first position in half toe standing and the ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position in flat foot. The between groups effect on ApEn of COP_R in the media-lateral direction was not significant, $F (2, 32) = 0.446$, $p > 0.05$.

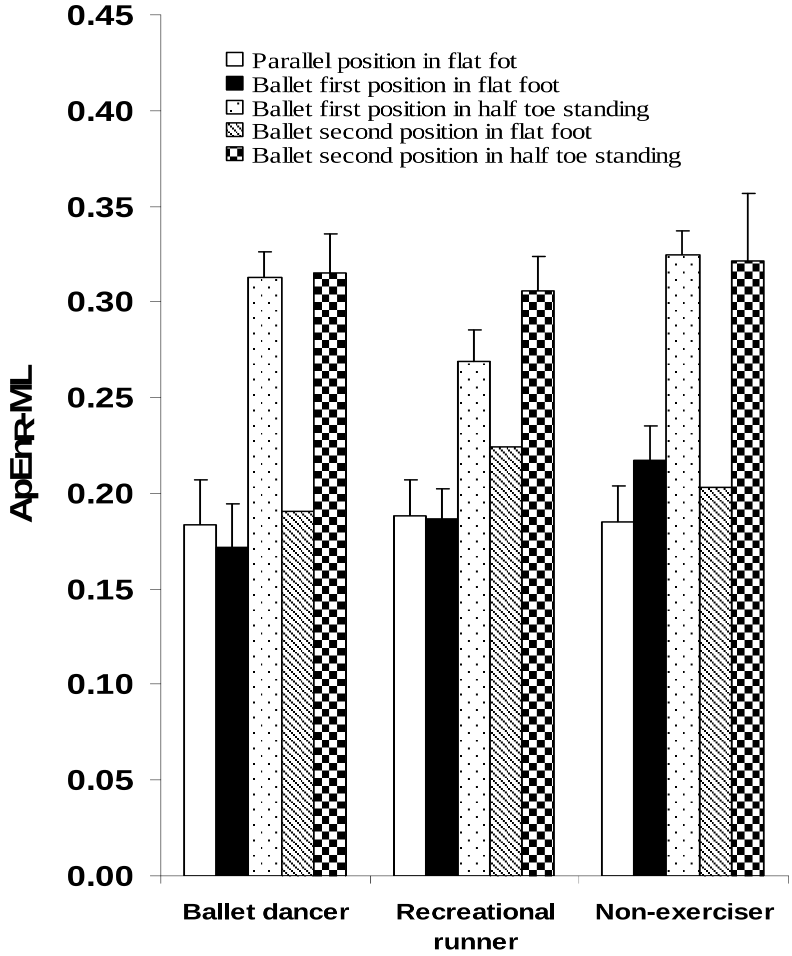

Fig.12: ApEn of COP_R - ML as a function of group and posture.

Anterior-Posterior ApEn of COP_R

The ApEn of COP_R in anterior-posterior direction of the within-subject posture effect was significant, $F (4, 128) = 121.242$, $p < 0.05$ (Figure 13). The highest irregularity was in the posture with the ballet second position in half toe standing. The posture with the lowest irregularity was the parallel position in flat foot. The pairwise comparisons showed the ballet first position in flat foot and the ballet second position in flat foot was significantly higher than the parallel position. The ballet first position in half toe standing and the ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position in flat foot. The between groups effect on ApEn of COP_R in the anterior-posterior direction was not significant, $F (2, 32) = 0.895, p > 0.05$.

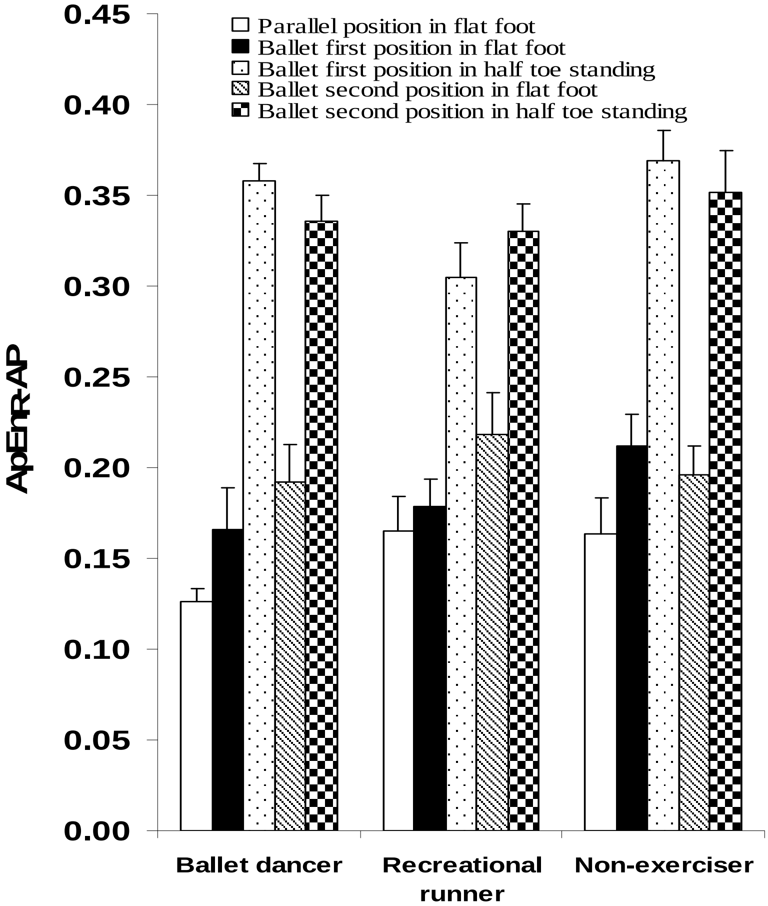

Fig.13: ApEn of COP_R - AP as a function of group and posture.

Medial-Lateral Cross ApEn COP_{net}

The result of Cross ApEn COP_{net} in medial-lateral direction within posture effect of the medial-lateral was significant, $F (4,128) = 67.571, p < 0.05$ (Figure 14). The posture with the coupling effect was ballet second position in half toe standing, indicated by the highest value averaged across subjects in the media-lateral Cross ApEn COP_{net}. The posture with the strongest coupling effect was ballet first position in half toe standing, indicated by the lowest value averaged across subjects in the media-lateral Cross ApEn COP_{net}. The pairwise comparisons showed the ballet first position in half toe standing and the ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position in flat foot.

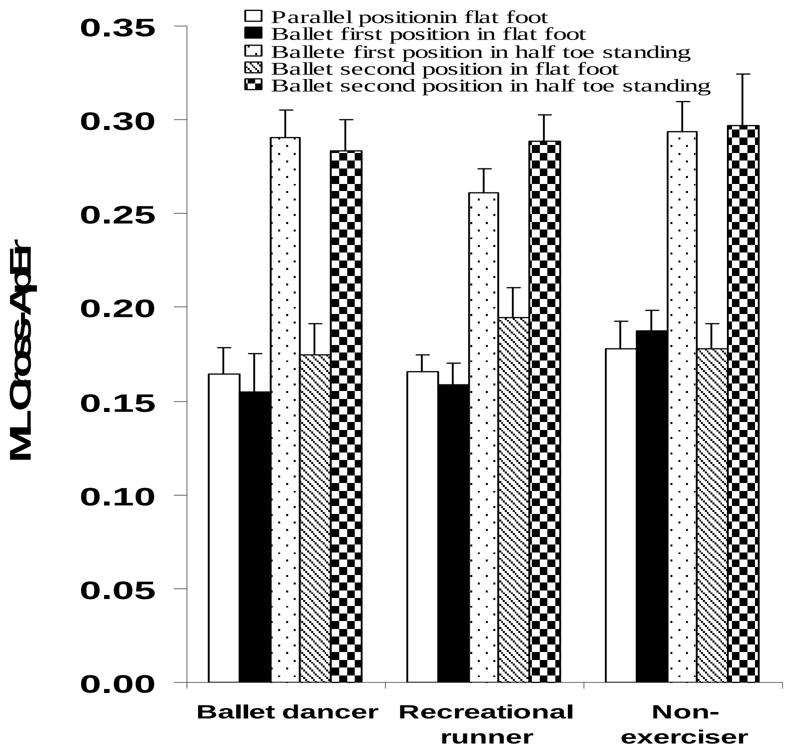

Fig.14: Cross ApEn - ML as a function of group and posture.

Anterior-Posterior Cross ApEn

The anterior-posterior Cross ApEn within postures effect was significant, F (4,128) =107.986, $p < 0.05$ (Figure 15). The posture with the lowest coupling effect was the ballet first position in half toe standing, indicated by the highest value averaged across subjects in the anterior-posterior Cross ApEn (Vaillancourt et al., 2006). The posture with the strongest coupling effect was parallel position in flat foot, indicated by the lowest value averaged across subjects in the anterior-posterior Cross ApEn. The pairwise comparisons showed the ballet first position in half toe standing and the ballet second position in half toe standing were significantly higher than the parallel position, the ballet first position in flat foot, and the ballet second position. The ballet second position in flat foot was significantly higher than the parallel position.

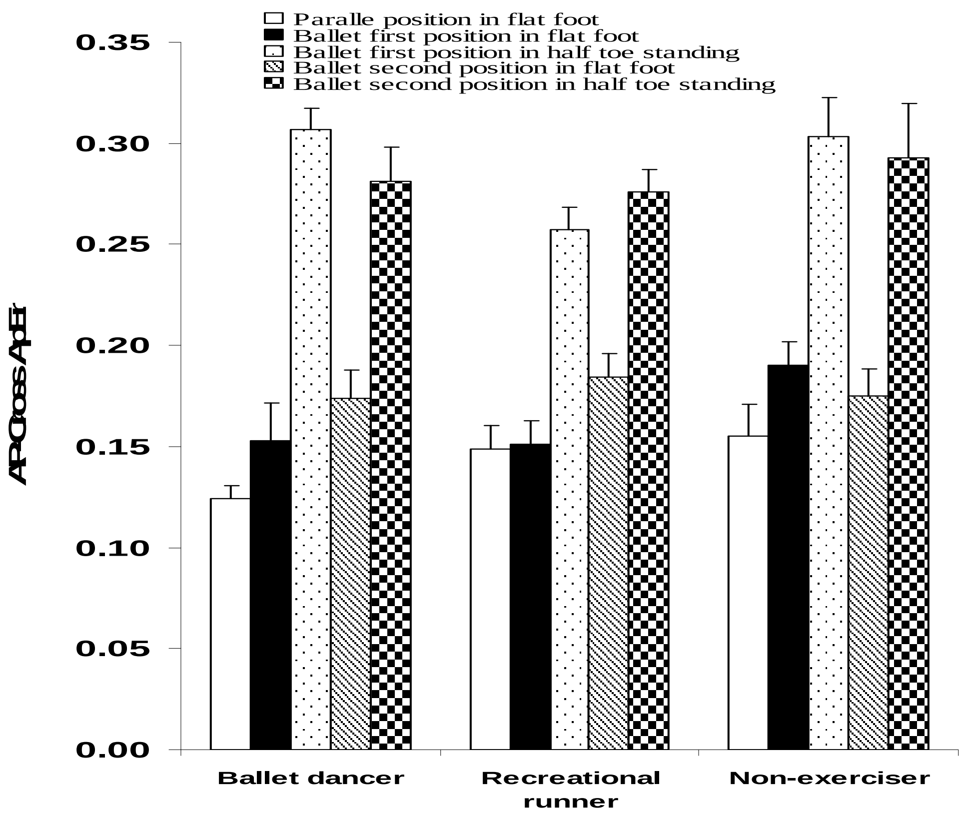

Fig.15: Cross ApEn - AP as a function of group and posture.

Chapter 4

Discussion

The purpose of this study was to investigate the amount and structure of posture variability and the coupling effect of individual foot COP in the different ballet postures between young female adult college ballet dancers, recreational runners and non-exercisers. It was hypothesized that, the college level ballet dancer, due to relevant specific practice experience would have less COP variability than the control groups. Previously, Gerbino et al. (2007) found that ballet dancers had better balance ability on the single leg performance. The posture control ability of ballet dancers has also been studied in rigid and foamed surface platforms with eyes open or closed (Crotts et al., 1996; Golomer et al., 1997a, b).

There have been no studies that have compared the toe standing posture between ballet dancers and control groups, and the coupling effect between left and right feet on half toe standing posture and flat foot posture. The half toe standing posture is one of the most important motor skills in ballet performance. The experienced ballet dancers have more training on half toe standing posture, compared with the recreational runners and non-exercisers.

This study compared the standard deviation of COP_{net}, COP_R, COP_L variability between the college level ballet dancers, recreational runners, and non-exercisers using two force platforms. The ApEn and Cross ApEn were determined and compared across these population groups. Schmit et al. (2005) found that the variability of postural sway did not reveal any differences between the dancers and track athletes in AP and ML directions, but instead differences were apparent in entropy analysis. In this study, the results also showed no significant difference in COP_{net} - ML/AP between the college level ballet dancers and the control groups. In the COP_R, COP_L in the medial-lateral direction, the non-exerciser group had the lowest amount of variability compared to the college ballet dancers and the recreational runners.

The COP_{net} variability in the medial-lateral and anterior-posterior directions was not significantly different between groups. This may be due to the participants' hip flexibility and the turn out angle of the postures. Due to their extra hip flexibility, the college ballet dancers could stand in the postures with a larger foot angle compared with the recreational runners and the non-exercisers. For example, it was observed that the college ballet dancers had the highest heel to ground height in the half toe standing, although no direct measures were taken, the analysis did not reveal a significant between group effect, Figures 2 and 3 show that the college ballet dancers had higher SD of COP_{net} in media-lateral and anterior- posterior directions. Simmons et al. (2004) found that dancers had more body sway than control group in AP direction, especially when somatosensory information was unreliable, and utilized a hip strategy to maintain balance. Golomer et al. (1998, 1999) found that ballet dancer's postural control was more variable in AP direction than ML direction, especially when the time period is more than 10 s.

There were significant effects of posture on the variability and coupling of COP. The parallel position in flat foot had the lowest variability, and the ballet first position in half toe standing had the highest variability. The parallel position in flat foot (the so-called quiet standing) could be modeled by an inverted pendulum, and controlled by ankle (plantar/ dorsiflexor) and hip (abductor/ adductor) in both the AP and ML direction, respectively (Winter et al., 1993). However, the base of support area is narrowed in the ballet first position in half toe standing as the participants used more lower body or even upper trunk degrees of freedom to maintain the posture.

The COP_L and COP_R in the ML and AP directions showed a significant difference between groups, and the non-exercise group had the lowest variability compared with dancers and recreational runners. This finding is consistent with the hypothesis that the non-exerciser group intuitively freezes the mechanical degrees of freedom to resist the potential perturbations from the challenged ballet posture. In the ML direction of the two platforms, the Cross-ApEn did not show a significant difference between groups.

Schmit et al. (2005) found that ballet dancers had more irregular patterns than the control group, and suggested that dancers have greater behavioral flexibility, allowing them to switch behavioral modes more easily. Stins et al. (2009) also found that dancers have more irregular COP fluctuations in postural sway, and interpreted dancer's balance as more automatized. In this study, there was a significant within group effect. The half toe standing postures had the higher Cross - ApEn value than the flat foot postures. So it was not just the half toe standing posture that led to higher variability of the COP_{net} in AP direction, but significantly that there were more irregular dynamic patterns related to the postures. These findings on ballet postural control reveal that the coupling features of the foot coordination dynamics cannot be evaluated using only correlations or other linear analysis methods to determine the relation between COP_L and COP_R (Winter et al. 1993, 1996).

In summary, the half toe standing posture is one of the most important motor skills in the ballet training. However, there was no previous study showing the COP of the postural control of ballet poses in half toe standing. The 2–platform protocol showed the individual foot coupling between physical activity groups as a function of posture. The study examined the postural control of ballet poses between the college level ballet dancers and control groups focusing on the direction of motion and coupling effect on the COP_{net}, COP_L, COP_R. The results suggest that postural control in the different postures is similar across exercise group. There was some evidence that the postural control in the non - exercise group reduced the motion of each individual foot COP in contrast to the exercise group.

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