Kinematics and aesthetics of grand battement and développé after static and dynamic hamstrings stretching in adolescents

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Abstract

Adolescent recreational dancers mostly use static hamstring stretching. However, dynamic stretching seems to influence athletic performance as well. Is one of these stretching methods more favorable to the execution of a grand battement or développé (two ballet movements) in dancers? Sixteen participants performed a grand battement and a développé under three conditions: without stretching, and immediately after the static and dynamic hamstring stretching. Three-dimensional kinematics of the lower limb performing the movement were recorded and analyzed. Dynamic stretching has the most noticeable effect on the amplitude of the grand battement, while the développé is not significantly modified by the stretching condition. Dynamic stretching appears to be helpful in the improvement of explosive movements. Correlations between the aesthetic evaluation of a jury made of professional dancers and kinematical parameters were studied. Significant linear correlations between kinematic parameters and aesthetic scores have been observed: improving dancers' physical performances has noticeable impact on the perception of their movements.

Keywords: dance, 3D kinematics, aesthetics, stretching, recreational dancers.

1 Introduction

From an early age, dancers are taught to use (prolonged) static stretching. According to the popular belief, 'when it hurts, it really works', dancers stretch as often and as long as possible until pain appears. Such beliefs about the practice of stretching probably originated in the same way as the aesthetic criteria of classical dance: passed on from teacher to teacher, they become a tradition. This type of discourses deserves to be re-evaluated from a scientific perspective.

There are many types of stretching: static, dynamic, ballistic, etc. (Apostolopoulos *et al.* 2015; Behm *et al.* 2016). Stretching of a muscle is either produced by the dancer himself by inducing an active movement or incited by an external force to increase the amplitude of the joint movement. Physiological changes in muscle and/or joint function induced by stretching do not necessarily have to be related to unpleasant sensations or even pain (Light *et al.* 1984). Dynamic stretching seems to be relevant in the context of dance practice, especially because of its positive impact on athletes' explosive performances (Behm & Chaouachi 2011).

We will assess the impact of static and dynamic stretching methods of hamstring muscles on dance movements by analyzing the three-dimensional kinematics of two basic ballet movements: the grand battement (Gb) and the développé (Dé) (Figure 1). Both movements have for initial and final positons a lower limb on the ground (*i.e.* the ground leg) with the hip in external rotation and the knee in full extension, this lower limb being called ground leg. The movement realized by the other leg is a combination of hip flexion and hip abduction and a knee also in full extension with the ankle in maximum plantar flexion.

Dancers' physical skills condition their ability to reach their aesthetics ambitions. Hence dancers have to find a balance between technical requirements that we define as the optimization of kinematical variables such as range of motion (ROM) and artistic expression (movement's aesthetics), the latter relying on their own criterions or to jury's ones. It is therefore tempting to hypothesize that kinematics and aesthetics are correlated (Bronner 2015). The aim of the present study is therefore twofold: to examine the influence of 3 conditions (*i.e.* without stretching or after static versus dynamic stretching) on the kinematics of Gb and Dé and to show the existence of kinematics/aesthetics correlations in young recreational dancers performing a Gb or a Dé.

Figure 1: Left panel: a grand battement (from https://www.larousse.fr/encyclopedie/images/Battements_en_premi%C3%A8re_position/1001660). Right panel: a développé (from https://www.youtube.com/watch?v=m4A6PLeGIB4).

2 Material and methods

Participants had to be an adolescent dancer, *i.e.* aged between 10 and 19 years (WHO, 2015). This age group is typical of private dance schools where recruitment took place; a basic curriculum begins at age 4 and ends at age 18. Dancers who have undergone musculoskeletal surgery within the past 6 months and/or have undergone physical therapy have been excluded, as well as the dancers with acute or chronic musculoskeletal injuries. Sixteen participants were selected (4 boys, 12 girls), with mean age 15.3 ± 2.8 years, mean Body Mass Index 21.4 ± 3.5 kg m^{-2}, and training an average of 8.8 ± 4.3 hours a week. A jury composed of 5 professional dancers was gathered (4 girls/1 boy, aged 25.8±4.1 years, dancing from 18.6±4.6 years, practicing 14.8±8.5 hours/week). They were blinded to the medical and artistic background of the participants.

Participants performed two movements, a Gb and a Dé, first without stretching (NS) and then immediately after dynamic stretching (DS) and immediately after static stretching of hamstring muscles (SS). The order of the stretchings was random. The dancer was required to take a 15 minute break to restore initial muscle stifness, more than the minimal 10 minutes required according to Mizuno *et al.*

(2012). The only given instruction was to 'do the best movement according to what teachers taught you'. All dancers performed the movements with the lower limb with which they were most comfortable.

Details about stretchings procedures were given to the dancers. Static stretching was carried out in a hamstring extension position for 30 seconds as suggested by Alshammari *et al.* (2019). The static stretching had to be performed twice on both lower limbs and on the subject's maximum passive joint amplitude below the pain threshold. Dancers were instructed to focus on the sensation of maximum stretching without any burning, tearing, tingling or shaking. The lower limb was placed on a wall so that the necessary range of motion was reached. Dynamic stretching consisted of throwing the lower limb forward with the knee extended and the ankle plantar flexed. Abduction was eliminated to increase hamstring stretching. Ten movements of each lower limb were performed at a frequency of 1Hz. Each movement had to cover the entire active joint range of motion of the subject (Behm *et al.* 2016).

Under all three conditions, the kinematics of the lower limb performing the movement was recorded by a VICON® system (Vicon Motion Systems Ltd, Oxford Metrics, Oxford, United Kingdom) at a sample frequency of 120 Hz. The VICON® system provides the positions over time of reflective markers placed on the participant and, in our case, the joint angles associated with the thigh, $\theta_{THI}(t)$, knee, $\theta_{KNE}(t)$, and ankle, $\theta_{ANK}(t)$ (Figure 2). Using these data, we calculated the corresponding joint amplitudes (ROM_{THI}, ROM_{KNE} and ROM_{ANK}) by the relation $ROM_i = \max(\theta_i(t)) - \min(\theta_i(t))$. The duration, *T*, of each movement, the maximum linear velocities reached by the thigh and ankle ($v^{max}{}_{THI}$ and $v^{max}{}_{ANK}$) and the dimensionless jerks (J_{ANK}, J_{KNE} , J_{THI}) were calculated from the angle time series. Dimensionless jerk is an observable related to kinematical motion's smoothness (Balasubramanian, 2012). Sample plots are shown in Figure 2. A video recording of the participants was also performed.

In addition to the kinematical evaluation, the video recordings allowed a qualitative evaluation of the aesthetic performances. Each member of the jury was asked to rate separately the participant's movements from a questionnaire inspired by Angioi *et al.* (2019). The total qualitative score (/32) was the sum of smoothness (/4), technique (/4) and global aesthetics subscores (/24).

The influence of stretching on the selected kinematic variables was evaluated by a one-way repeated measures ANOVA (factor: NS, SS, DS). In case of significant influence of stretching, a post-hoc Holm-Sidak analysis was performed to compare the conditions. The statistical analysis was performed with Sigmaplot® (v.11.0 Systat Software, San Jose, CA, United States of America). A p-value of 0.05 was set as the significance threshold for all tests. Pearson correlation coefficient *r* were computed between all the pairs of computed parameters (kinematical and qualitative scores). *r* values >0.3 were considered as relevant. Kendall τ coefficients were computed to check the global agreement between the different members of the jury, for the different subscores and for the total qualitative score. The latter computations were made using R free software.

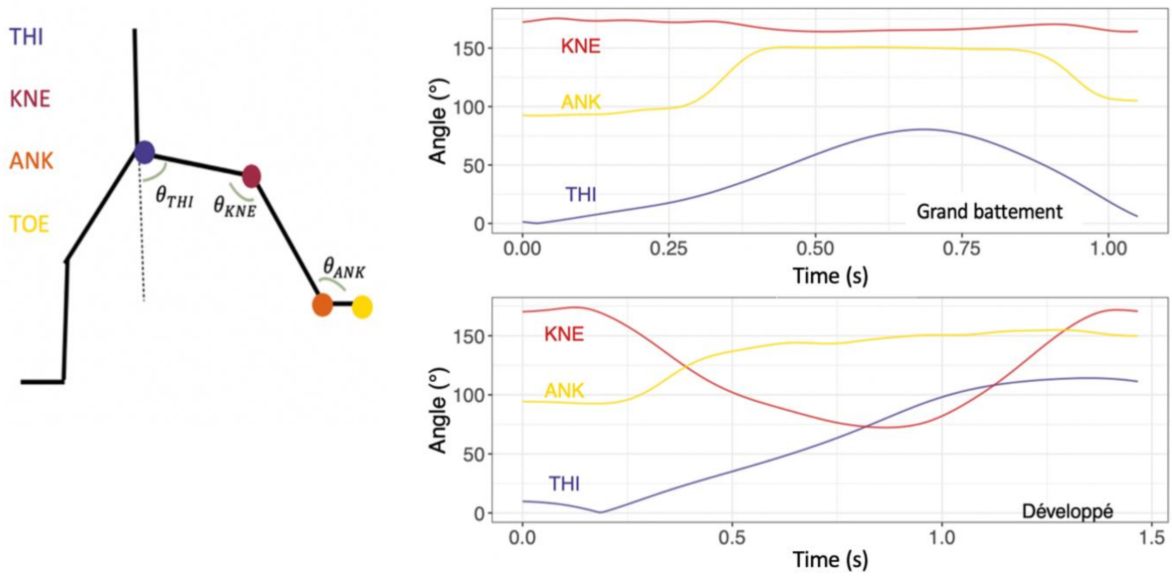

Figure 2: Left: Schematic representation of some registered markers: thigh (THI), knee (KNE), ankle (ANK), foot (TOE). Also shown are the angles of the thigh (θ_{THI}), knee (θ_{KNE}) and ankle (θ_{ANK}). Right: Typical traces of these angles over time during the two movements performed. The anatomical landmarks used for the placement of the markers are precisely defined by the plug-in-gait model of the lower limbs proposed by VICON® (VICON, 2017).

3 Results

Table 1 shows the results of the ANOVA. Data written in bold font illustrate kinematic parameters significantly influenced by stretching. Duration of the Dé is almost significantly affected by stretching (p=0.058) and will be considered significant thereafter. Gb duration, maximum ankle speed and thigh amplitude were found to be significantly influenced by stretching for the Gb.

Post-hoc analysis highlights several significant differences for the Gb (Table 2). The comparison between NS and DS conditions showed the most significant results. Only one result can be noticed for the Dé: an almost significant difference in duration between the SS and DS conditions.

Minimal and maximal Kendall coefficients are shown in Table 3 for the Gb and Dé movements and subscores. In most cases the agreement between the members of the jury can be considered as satisfactory. The best agreement between members of the jury is observed for the Gb. Pearson's correlation coefficients between the different computed parameters are summarized in Figure 3. In the case of Gb, the most noticeable correlations are observed between thigh's maximal speed (v_{THI}^{max}) and the jury's scores, between thigh's amplitude (ROM_{THI}) and the jury's score, and between thigh's kinematical smoothness (J_{THI}) and the technique subscore. In the case of Dé, correlations are mostly observed between T and the other kinematic variables. No correlation has been found between kinematic variable and jury's scores. In both movements, the technique and smoothness subscores are correlated with the global aesthetics one.

	Condition	T (s)	v^{max}_{ANK} (m/s)	v^{max}_{THI} (m/s)	ROM_{THI} (°)	ROM_{KNE} (°)	ROM_{ANK} (°)
Gb	NS	1.26 ± 0.24	4.94 ± 1.15	1.22 ± 0.48	97.9 ± 15.5	14.5 ± 11.0	45.5 ± 5.1
	SS	1.19 ± 0.23	5.57 ± 0.95	1.33 ± 0.41	103 ± 14	17.8 ± 13.1	48.6 ± 7.3
	DS	1.09 ± 0.18	5.65 ± 1.02	1.34 ± 0.46	106 ± 14	18.8 ± 13.9	48.2 ± 16.8
	p	**0.029**	**<0.001**	0.220	**0.007**	0.318	0.626
Dé	NS	2.61 ± 1.06	3.24 ± 0.95	0.72 ± 0.17	103 ± 12	112 ± 8	53.3 ± 6.7
	SS	2.76 ± 1.43	3.39 ± 0.95	0.76 ± 0.30	103 ± 13	112 ± 8	55.2 ± 5.5
	DS	2.29 ± 0.97	3.45± 1.03	0.72 ± 0.30	106 ± 11	109 ± 29	52.8 ± 6.6
	p	**0.058**	0.666	0.679	0.307	0.778	0.139

Table 1: Results of one-way repeated measures ANOVA for the calculated kinematic parameters. The data are presented as mean ± standard deviation. Dimensionless jerks are not displayed since they do not lead to differences worth to be discussed.

	Comparaison	T	v^{max}_{ANK}	ROM_{THI} (°)
Gb	NS vs SS	0.247	**<0.001**	0.069
	NS vs DS	**0.026**	**<0.001**	**0.007**
	SS vs DS	0.213	0.626	0.264
Dé	NS vs SS	0.983		
	NS vs DS	0.104		
	SS vs DS	0.07		

Table 2: Results of the Holm-Sidak post-hoc for the parameters significantly modified by the condition.

	Kendall	**Technique**	**Smoothness**	**Global**
Gb	Min	0.31 (0.01)	0.24 (0.03)	0.37 (<0.01)
	Max	0.59 (<0.01)	0.58 (<0.01)	0.59 (<0.01)
Dé	Min	0.28 (0.04)	0.31 (<0.01)	0.36 (<0.01)
	Max	0.44 (<0.01)	0.47 (<0.01)	0.49 (<0.01)

Table 3: Minimal and maximal Kendall coefficients computed by comparing pairs of scores given by members of the jury to the same participant's movement. p-values are indicated between parentheses.

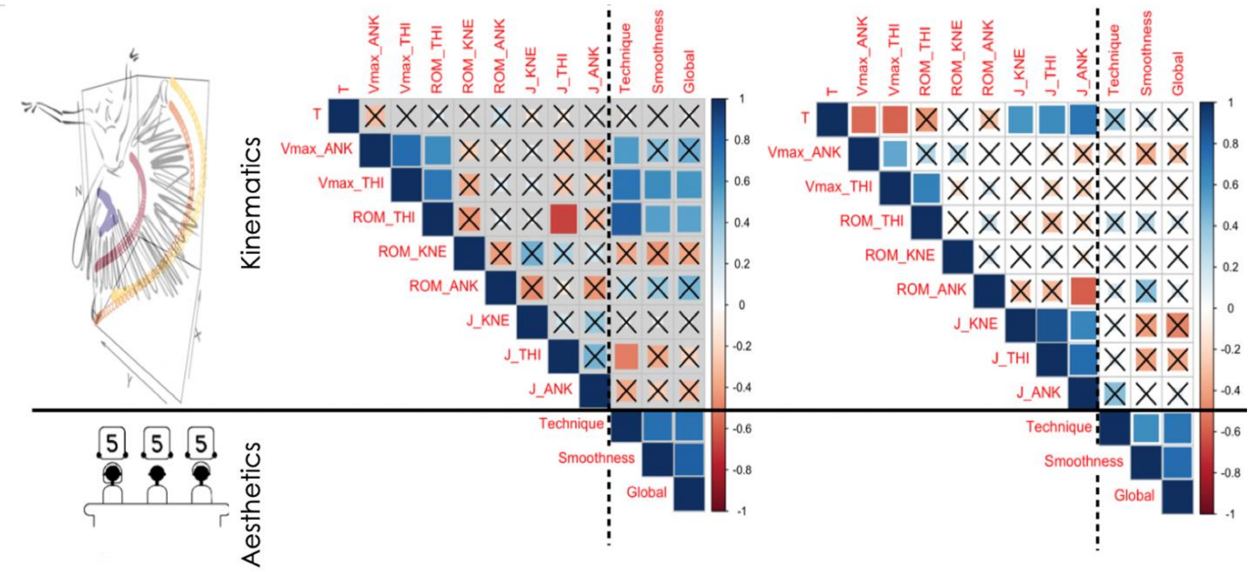

Figure 3: Left: Correlation plot for the different computed parameters in grand battement. Crosses denote nonsignificant correlations (p>0.05). Right: Same for the développé. Pearson's correlation coefficient magnitudes are proportional to the areas of the squares; their signs can be deduced from the color scale.

4 Discussion

The results of the current study reveal that dynamic stretching has the most noticeable effect on the amplitude of the grand battement, while the développé is not significantly modified by the stretching conditions. Previous studies have demonstrated a relationship between the audience's aesthetic appreciation and changes in dancers' postures over a 58-year period. Based on records from the Royal Ballet Opera House in London, Daprati *et al.* (2009) found that dancers use increasingly greater amplitudes over time. Two explanations have been put forward: the first is that dancers' technical abilities have evolved due to better training methods; the second is that aesthetic preferences of directors and audiences have changed. One of the parameters of greatest concern to dancers today is therefore thigh amplitude since it is correlated to the aesthetic perception of their movements. According to our results, only dynamic stretching significantly increases thigh amplitude for the grand battement. It was expected according to Opplert & Babault (2018): Dynamic stretching causes an increase in muscle temperature which, in turn increases the elasticity of the tendons and decreases the viscous resistance of the muscles. The musculo-tendinous stiffness is eventually decreased and may lead to the observed improvement in amplitude after dynamic stretching.

It has been observed in our subjects that static and dynamic stretching increase the maximum speed of the ankle during the grand battement and that dynamic stretching significantly decreases the duration of the movements. Opplert and Babault (2018) and Amiri-Khorasani et al (2016) also found and increased speed in explosive performance after dynamic stretching. For example, the aim of the latter study was to compare the impact of different stretchings, separately or combined, on the speed and acceleration of 20 professional footballers. It was found that dynamic stretching was more effective than static stretching for sudden movements. The mechanism proposed to explain the impact of dynamic stretching on speed is similar to that previously summarized in our discussion regarding increased amplitude (Amiri-Khorasani *et al.* 2016). We also found a significant increase in the maximum speed of the ankle for static stretching. According to the review by Behm & Chaouachi (2011) and to the study of Chaouachi *et al.* (2017), this stretching can improve performance if performed in short cycles. We did not perform a cycle, however we chose the 30-second threshold as recommended by Alshammari *et al.* (2019).

Correlations between kinematic variables and aesthetic perception have been found mostly in grand battement. The most obvious one is between thigh amplitude (ROM_{THI}) and the jury's scores. Such a link between 'beauty' and amplitude of movement was found in professional dancers in Torrents (2013). Fast grand battements also appear to be positively perceived by the jury: grand battement has to be an explosive movement. The negative correlation between thigh's jerk (J_{THI}) and the technique-related score shows that the jury favours grand battements with low jerk. This result suggests that low jerk may indeed be an indicator of high perceived smoothness. No correlation of this type has been found in développé. It is likely that the jury's artistic perception is not limited to lower limb in this complex movement. We notice however that the dancers performing slower développés show higher jerks. Reaching a good control of smoothness is more difficult at low speed, especially in recreational dancers.

The results of the current study should be seen in the light of some methodological limitations. Muscle activity before and after the stretchings was not measured in the present study. However, the work of Fletcher (2010) provides information about stretching impact on muscle activity. She included 24 men, with an average age of 21 years, and compared slow and fast dynamic stretchings to see their effects on muscle activity during jumping performance. It was concluded that during rapid dynamic stretching, there was a significant increase in amplitude on the electromyogram, *i.e.* an enchanced muscle activity. Another limitation of our methodology is that we focused on the lower limb and neglected movements of the whole body. These movements could be impacted by stretching and have a role in aesthetic evaluation. We hope to address that limitation in future works.

5 Conclusion

Through this study of adolescent recreational dancers, we demonstrated the effectiveness of stretching in improving performance indices (duration, amplitude and maximum speed) measured during a grand battement and a développé. Dynamic stretching leads to larger modifications than static stretching. It significantly increased maximum ankle speed and thigh amplitude, and decreased the duration of the grand battement in our participants. We would therefore encourage dancers to incorporate dynamic stretching into their warm-ups, especially before a performance with explosive movements. Moreover, kinematical parameters have been shown to be correlated to a jury's aesthetic appreciation. Hence improving kinematical parameters has an impact on artistic perception of one dancer's movement.

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