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Original articles

Relationship between age, length of experience and weekly dance frequency with the stability of the lower limbs of dancers

Relação entre idade, tempo de prática e frequência semanal de dança com a estabilidade dos membros inferiores de dançarinos

Relación entre la edad, el tiempo de práctica y la frecuencia semanal de danza con la estabilidad de los miembros inferiores de los bailarines

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Keywords:
Posture;
Joint instability;
Dancing;
Dance class.

ABSTRACT
The aim of this study was to correlate age, length of experience and weekly frequency of dance practice with the dynamic alignment of lower limb joints in dancers. A total of 339 dancers with 5 or more years of dance experience participated. Participants answered the anamnesis and underwent a joint alignment evaluation specific for dancers (MADAAMI-II). Kendall's Tau was applied to correlate age, length of experience, and frequency of dance practice with the MADAAMI-II scores. The correlation between the general, pelvis, and knee stability scores with the weekly frequency was positive ($p<0.001$). These findings suggest that a higher weekly frequency of dance training is associated with better joint stability.

Palavras-chave:
Postura;
Instabilidade articular;
Dança;
Aula de dança.

RESUMO
O objetivo deste estudo foi correlacionar idade, tempo de prática e frequência semanal de prática em dança com o alinhamento dinâmico das articulações de membros inferiores em dançarinos. Participaram 339 dançarinos, com 5 ou mais anos de experiência em dança. Os participantes responderam a anamnese e foram submetidos a uma avaliação do alinhamento específica para dançarinos (MADAAMI-II). O Tau de Kendall foi aplicado para correlacionar idade, tempo de prática e frequência de prática em dança com os escores do MADAAMI-II. A correlação entre os escores de estabilidade geral, da pelve e do joelho com a frequência semanal foi positiva ($p<0,001$). Esses achados sugerem que uma maior frequência semanal de treinamento de dança está relacionada a uma melhor estabilidade articular.

Palabras clave:
Postura;
Inestabilidad articular;
Baile;
Clase de baile.

RESUMEN
El objetivo de este estudio fue correlacionar edad, tiempo de práctica y frecuencia semanal de práctica de danza con el alineamiento dinámico de las articulaciones de los miembros inferiores en bailarines. Participaron 339 bailarines con 5 o más años de experiencia en danza. Los participantes respondieron una anamnesis y se sometieron a una evaluación específica para bailarines (MADAAMI-II). Se aplicó el Tau de Kendall para correlacionar edad, tiempo de práctica y frecuencia de práctica con las puntuaciones de MADAAMI-II. La correlación entre las puntuaciones de estabilidad general, pelvis y rodilla con la frecuencia semanal fue positiva ($p<0,001$). Estos hallazgos sugieren que una mayor frecuencia semanal de entrenamiento de danza se relaciona con una mejor estabilidad articular.

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INTRODUCTION

Stability is an aspect of posture characterized by the ability to maintain the center of body mass adjusted over its base of support (Nashner et al., 1988). It is stability that supports and balances the body segments in relation to each other (Bouisset and Do, 2008) in static and dynamic postures (Mochizuki and Amadio, 2003).

To perform a dance sequence, joint alignment must be altered and recovered in the transition between one step and another. During dance movements, it is essential that dynamic stability is preserved to enable the dancer to achieve appropriate figures when performing choreographies (Lin et al., 2019). In addition, in classical *ballet*, the execution of movements with large ranges of motion of the lower limbs in *en dehors* - maximum external rotation that positions the feet in a longitudinal line of (preferably) 180º - requires great postural stabilization skills (Lai and Kruse, 2016; Michalska et al., 2018).

Throughout dance training, dancers need to first learn the most basic steps that serve as a technical foundation and then move on to the more complex steps. The more complicated the dance step is, the longer the training time and, consequently, the dance experience required to perform it (Lin et al., 2019). The difference in the training of technical skills between experienced and inexperienced dancers can lead to the development of different postural control strategies and abilities to resist changes in balance (Crotts et al., 1996; Lin et al., 2019).

There is already evidence that experienced dancers have better postural stability than novice dancers (Rein et al., 2011; Lin et al., 2014, 2019), so it is presumed that the greater experience in years of dance training is also related to better lower limbs joint alignment. Nonetheless, understanding the postural stabilization strategies utilized by advanced dancers can help less experienced dancers progress in dance through dance-focused stability training (Rein et al., 2011). In this context, the aim of this study was to correlate age, length of training experience and weekly dance frequency with the stability of dancers' lower limbs.

METHODS

This study utilized an *ex post facto* correlational design. The sample was probabilistic, composed by Brazilian dancers of both sexes present at the 40th Dance Festival in Joinville, SC. The sample size was calculated in the Gpower 3.1.7 software, using the Exact family of tests (Correlation Bivariate Model), assuming an average Cohen effect size of 0.3 (based on initial expectation), an alpha of 0.05 and a power of 80%, requiring a minimum of 252 dancers in total.

The inclusion criteria were: being at least 15 years old, having 5 years of experience in classical *ballet* and practicing classical *ballet*, jazz dance or contemporary dance at the time of evaluation. Exclusion criteria were the presence of surgeries on the lower limbs with placement of knee and hip prosthesis.

DATA COLLECTION

Data collection took place from July 17th to 28th, 2023 in Joinville - SC, at the 40th Joinville Dance Festival. The festival is the largest in number of participants since 2002, according to Guinness World Records ("Most performers in a dance festival", 2002) and features competitions and classes in various dance styles (Guinness World Records, 2002). The dancers were invited to participate in the research through flyers and posters displayed at the Festival. The dancers who sought evaluation and fulfilled the inclusion criteria signed the free and informed consent form – TCLE – and were sent to the evaluation. This study was approved by the Research Ethics Committee of the University where it was carried out (Ethics opinion number: 6,051,753).

Initially dancers answered a questionnaire to obtain data such as age, dance style, length of experience and frequency of dance practice at the time of the evaluation or within the past month. Subsequently, the protocol of the Dynamic Evaluation Method of Lower Limb Joint Alignment (MADAAMI-II) was carried out with the intention of pointing out compensations and misalignments that may be present when performing a dance (Gontijo et al., 2018). The environment was previously prepared according to the specificity of MADAAMI-II. In the space provided by the Festival, using an area around 4 m^2, angles of 120° and 180° were marked indicating the location for positioning the dancer's feet (Figure 1a). A plumb line was placed in front of the angle markings and a digital camera (Sony Cyber-shot-hx-100- 30x) was positioned on a 0.47 m high tripod, 1.75 m in front of the plumb line.

DYNAMIC EVALUATION METHOD OF LOWER LIMB JOINT ALIGNMENT (MADAAMI-II)

The following anatomical points were palpated and marked in the right lower limb: right posterior superior iliac spine (PSIS), right anterior superior iliac spine (ASIS), anterior tuberosity of the tibia, medial malleolus, lateral malleolus, navicular bone and second toe. Spherical markers were placed on these points using a transferable tape. Afterwards, the dancers were positioned on the markings on the floor, with a plumb line in front, aligned with the second toe (Figure 1b).

A sequence of the MADAAMI-II *demi-plié*, *grand-plié* and *fondu* steps was taught and reproduced in two situations: (1) first position of the feet in the dancer's usual *en dehors* and (2) first position with an angle of 120°. These steps include a descending phase, characterized by triple flexion of the hip, knee, and ankle, and an ascending phase, during which the dancer returns to the initial position with hip and knee extension. The *demi-plié* (from French, meaning half bend) is performed up to half the flexion range with both feet fixed on the floor, while the hips increase external rotation and abduction.

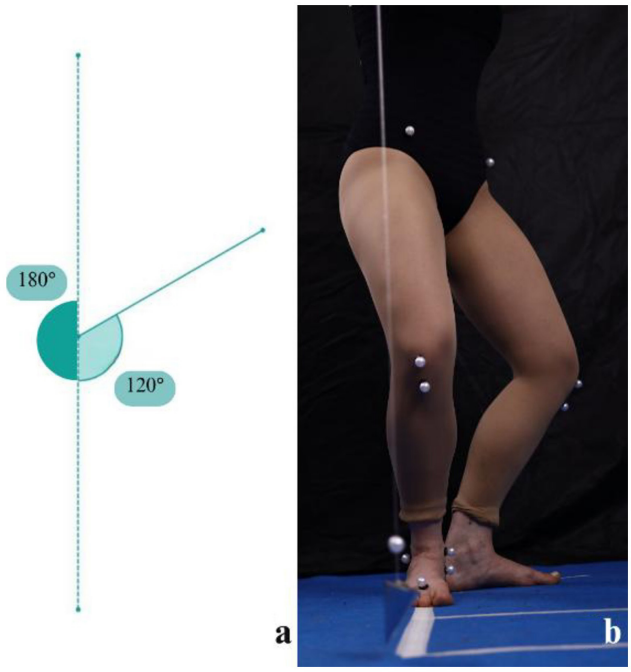

Figure 1. Positioning the dancer to perform the MADAAMI-II protocol (a) Representation of the angles indicating the location for the positioning of the dancer's feet; (b) positioning the dancer to perform the MADAAMI-II protocol.
Source: authors' archives, 2024.

The *grand-plié* (from French, meaning deep bend) involves maximal flexion, abduction, and external rotation, allowing the heels to lift off the floor to increase the range of the movement. The *fondu* is performed in single-leg support, where the supporting leg performs triple flexion in half depth without removing the heel from the ground. In the MADAAMI-II protocol, the contralateral leg remains positioned in external rotation, with the foot resting against the posterior aspect of the supporting leg in the *coupé derrière* position. Two repetitions were practiced for rehearsal and the third was recorded with the camera positioned in front of the right foot.

The videos were transferred to a computer and analyzed always by the same evaluator, following the guidelines of MADAAMI-II: filling out the score sheet (Annex A) and calculating the stability scores. Individual scores were calculated for the foot, knee and pelvis domains and the general stability score was given by the sum of all domains (total score). All scores were calculated for both situations: with feet positioned on self-selected *en dehors* and on 120° *en dehors*.

To analyze the steps of MADAAMI-II, each movement, in each position of the feet, was separated into the following phases: extended knee (initial position), descent, point of greatest static amplitude and ascent. Each phase received a score from one (1) to four (4) according to the criteria for each domain and, at the end of the analysis, the points of the sequence of steps were added together, generating the scores.

The **foot alignment** was classified as stable and unstable according to the movement of the arch of the foot. If the arch of the foot sustained its position from start to finish, it received 3 points and was considered stable. It was considered unstable when performing supination, hanging towards the 5th finger (2 points), or a pronation, hanging towards the 1st finger (1 point). The foot score has a minimum score of 24 points and a maximum of 72 points.

The **knee alignment** was classified as stable and unstable according to the projection of the marker of the anterior tibial tuberosity (ATT) in relation to the marker of the second toe. In static phases, the knee was considered stable when the ATT marker was above the 2nd/3rd finger (3 points), and unstable when the ATT marker was over the 4th/5th finger (2 points) or over the 1st finger (1 point). In the dynamic phases, it was considered stable when the ATT projection preserved the alignment from the initial phase to the final phase (4 points) and unstable when the anterior tuberosity started in internal rotation and moved, with its marker projecting towards the 2nd /3rd finger (3 points), 4th/5th finger (2 points) or 1st finger (1 point) at the end. The knee score has a minimum score of 24 points and a maximum of 84 points.

The **pelvic alignment** was classified as stable and unstable according to the anterior and posterior pelvic tilt, during executions in self-selected *en dehors* and 120° *en dehors*. The pelvis was considered stable when the PSIS and ASIS markers were aligned in the same position from the beginning to the end of the movement, marking 3 points. It was unstable when the leveling of the PSIS with the ASIS changed, leaving the posterior marker higher than the anterior marker (2 points) or lower than the same (1 point). The pelvis score has a minimum score of 24 points and a maximum of 72 points.

STATISTICAL ANALYSIS

Data were tabulated in Excel, version 2016 and analyzed using JASP software, version 0.19.0. For the purposes of statistical analysis, the sample was divided into three groups, by the clustering method, using the independent variables: length of experience (years), weekly frequency (hours) and age (years) (Figure 2). This three-group division aimed to identify distinct practice profiles within the sample and to enhance the interpretation of the findings. The Kolmogorov-Smirnov test was used to determine the normality of the independent variables. Descriptive data from the three groups were analyzed for all dependent variables (MADAAMI-II scores) and independent variables. Kendall's Tau correlation statistical test was used to generate the correlation between MADAAMI-II scores and the variables length of experience, weekly frequency and age. The significance level adopted was 0.05.

RESULTS

The sample consisted of 339 dancers, of which 91% were female and 9% male; 63% practiced classical *ballet* and other dance styles, 28% only *ballet* and 9% have practiced *ballet*, but practiced only another style in the time of evaluation. As for the region of Brazil to which the dancers belonged, 56% were from the southeast region of Brazil, 33% were from the south region, 7% the central-west region, 3% the northeast region and 1% from the north region.

In the analysis of the total sample, there was no correlation between the MADAAMI-II scores and age and length of experience, but there was a positive correlation between the scores that demonstrate general, pelvic and knee stability with the weekly frequency in hours of dance practice (Table 1).

In the analysis of the sample separated by groups, group 1 (n=68) was composed of dancers with longer dance experience, older age and low weekly class frequency. Group 2 (n=210) was made up of dancers with less dance experience, less age and low weekly frequency. Group 3 (n=61) was formed by dancers with shorter dance experience, younger age and high weekly class frequency (Table 2).

Table 3 presents the MADAAMI-II score values for each group separately. It was noted that there is a certain similarity between the median scores for the three groups. As for correlation, in the analysis by groups, it was observed that only group 2 obtained significant correlations between the weekly dance frequency and MADAAMI-II general, knee and pelvis scores (Table 4).

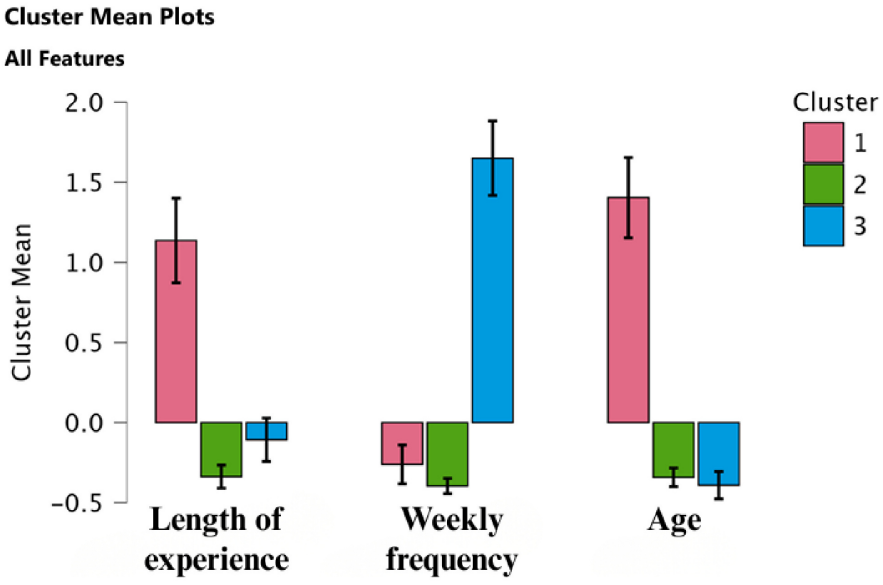

Figure 2. Clusters division Division of the sample into three groups based on the clustering, where each Cluster represents a group.
Source: authors' archives, 2024.

Table 1. Tau's correlation between the scores of the MADAAMI-II and independent variables (n=339).

	Foot	Knee	Pelvis	General
Age	0.024	0.042	0.028	0.019
Length of experience	0.018	0.060	0.049	0.032
Weekly frequency	0.007	**0.153***	**0.131***	**0.124***

*Significant correlation, p<0.001.
Source: Authors' analysis, 2024.

Table 2. Characterization of the sample separated by groups.

Group	Age (years)			Weekly Frequency (hours)			Length of experience (years)		
	1	2	3	1	2	3	1	2	3
Median (Minimum-Maximum)	28 (16-58)	17 (15-30)	18.16 (±2.9)*	6.5 (1-30)	6 (1-17)	20 (16-60)	18.5 (2-41)	10 (2-20)	11.4 (±3.8)*
Kolmogorov-Smirnov Test	p=0.007	p<.001	p=0.084	p=0.041	p<.001	p<.001	p=0.007	p=0.054	p=0.418

*Data that presented a normal distribution, which is why they are presented as mean and standard deviation.
Source: Authors' analysis, 2024.

Table 3. Descriptive statistics of the MADAAMI-II scores.

Group	Foot			Knee			Pelvis			General		
	1	2	3	1	2	3	1	2	3	1	2	3
Median	40	40	41	48.5	46	51	49.5	50	51	136.5	132	143
Minimum	24	20	26	24	22	28	23	2	14	101	67	98
Maximum	63	66	64	75	70	70	60	66	68	184	185	182

Source: Authors' analysis, 2024.

Table 4. Tau's correlation between weekly dance frequency and MADAAMI-II scores.

	Foot	Knee	Pelvis	General
Group 1 (n=68)	-0.033	0.320	0.033	0.053
Group 2 (n=210)	-0.040	**0.165***	**0.137***	**0.101***
Group 3 (n=61)	-0.073	0.144	0.071	0.083

*Significant correlation, p<0.05. Source: Authors' analysis, 2024.

DISCUSSION

The relevance of this research lies in the importance of evaluating if the frequency of dance practice contributes to good stability of Brazilian dancers, identifying the trends and misalignments during basic *ballet* steps. The findings of the study indicate that there is a weak and positive correlation between weekly frequency (in hours) and stability, given by the pelvis, knee and general scores of MADAMI-II, however they do not show any relationship with the experience (in years) of dance practice or the age of the dancers.

Other studies with professionals or pre-professionals dancers suggest that years of practical experience are related to stability (Crotts et al., 1996; Lin et al., 2014, 2019; Orishimo et al., 2009). However, there was a divergence between the populations studied. In the present study, the sample was mainly composed of amateur dancers, whose dancers with the longest period of practice were adults who did not have dancing as a profession and the dancers with the shortest period of practice were young people with more time available to practice dancing. This characteristic of the profile of the sample studied could be one of the factors that led the study to show no correlation between the length of dance experience (in years) and the joint stability of the lower limbs, as hypothesized.

According to Blanco et al. (2021), professional dancers have more hours of dance practice per week than amateurs, which requires them to perform dance movements more often, leading them to develop specific skills, such as power, to support choreographic demands. By this logic, stability is a skill that can be worked on specifically for dance. From this perspective, it was possible to note that professional dancers not only have more years of experience, but also a greater frequency of practice, denoting that there is a correlation between frequency and postural stability. This supports the findings of the present study, which suggest that the higher the weekly practice frequency, the more adequate the joint alignment.

Expertise in dance requires a greater capacity of the postural system to manage instability during performance and, therefore, body skills such as balance specific to the techniques of dance styles (Hugel et al., 1999; Michalska et al., 2018). For Lin et al. (2014), dance training is discrepant between levels of expertise, since advanced dancers widely use center and diagonal exercises, while beginner dancers stay longer at the *barre*. This difference influences the acquisition of postural skills, since the center and diagonal exercises make maintaining the *en dehors* and the joint stability more challenging due to the lack of support from the bar. Considering our results, it was possible to conceive that the lack of relation between

length of experience and the correlation between weekly frequency and stability was due to the fact that the more experienced dancers in our sample trained less hours per week. This could mean they spent less time dancing away from the bar to keep the joint stabilization skills as satisfactory as in the dancers' who trained more hours.

This understanding is also defended by Bruyneel et al. (2010), in a study in which adult dancers (professionals) achieved better postural stability than young dancers (pre-professionals) due to a greater number of hours danced, with the young group having an average of 14.4 ± 8.49 hours and the adult group 23.8 ± 10.61 hours. In this regard, they assumed that dancers with a lower weekly training frequency spend less time practicing away from the barre, thereby developing less postural stabilization skills. Therefore, it was speculated that the positive relationship found in our study between practice frequency and overall, pelvic, and knee alignment may be due to the fact that dance training exerts specific effects on balance control (Lin et al., 2014). We hypothesized that as the weekly frequency of practice increased, so did the time dancing away from the *barre*, which might have challenged dancers to improve their skills of maintaining proper joint alignment and led to the correlation observed.

By classifying our sample, a group of dancers with a longer practice history of practice experience, little weekly frequency and older age (group 1) was generated, a group with a moderate practice history, little weekly frequency and younger age (group 2), and a group with little a shorter practice history, high weekly frequency and medium age (group 3). Group 3 had the best scores on MADAAMI-II and group 2 had the lowest scores (Table 3). Bruyneel et al. (2010) findings can be compared with the median of weekly frequency of groups 2 and 3 and their respective stability scores. Group 3 had a median of 20 hours of practice and the best scores on MADAMI-II, while group 2 had a median of 6 hours dancing and lower scores - in agreement with Bruyneel's study, the group with more hours of practice achieved greater stability when compared to a group with fewer hours of training.

When MADAAMI-II scores were correlated with weekly frequency, group 2 was the only one that showed significant correlations (Table 4). These results again signal that the higher the frequency, the better the stability. On the contrary, in the context of group 2, the lower weekly frequency of dance hours is related to the lower stability of the dancers. One possible explanation for the fact that only the second group showed statistically significant results is that, although their scores were lower, the difference in alignment scores between one group and another was not particularly pronounced, whereas the difference in weekly practice hours between groups 2 and 3 was notable.

Currently, there is an increasing emphasis on controlling the dynamic alignment of the lower limbs so that during dance movements (in *en dehors* or in parallel) the center of the patella remains aligned with the second metatarsus (Orishimo et al., 2009). Although this movement towards a greater care for joint health in dancers is recent, it is believed that dancers with greater weekly frequency are practicing the technique more attentive to the correct alignment of the lower limbs, which makes them more stable.

Although dance is physically demanding, it differs from sports in that it is, above all, an artistic expression (Toledo et al., 2004), therefore, it is crucial that stability is associated with aesthetically impeccable performance. For Blanco et al. (2021), professional dancers who experience more hours of practice have great differences in performance skills when compared to dancers with less practice frequency. Dancers are trained in specific movements and sequences, repeated exhaustively during classes (Orishimo et al., 2009). The more complex movements - and the ones that require greater stability – are the result of accumulated experience and the quality of performance is a product of the skill level (Lin et al., 2019). Thus, increasing weekly frequency leads to increased dynamic stability and also results in improved technique.

The main limitation of this study was the composition *in retrospect* of the groups, generating groups with different sample sizes and with little distinction between the weekly frequency of dancing hours. Another important limitation is that dance level data was not collected.

CONCLUSION

The results showed a weak, positive and significant correlation between the joint alignment of the lower limbs and the weekly frequency in hours of dance practice. The higher the MADAAMI-II scores - general, pelvis and knee -, the greater the weekly frequency of hours of dance practice. When divided into groups, dancers who had a higher weekly frequency also achieved the best stability scores, while those with a lower weekly frequency had the lowest scores. Furthermore, the results also demonstrated that the length of dance experience, in years, and the age of the dancers have no correlation with joint stability of the lower limbs.

FUNDING

This study did not receive financial support of any kind for its execution.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest

DATA AVAILABILITY

The datasets generated and analyzed during the current study are not publicly available due to ethical constraints, but will be provided by the corresponding author upon reasonable request.

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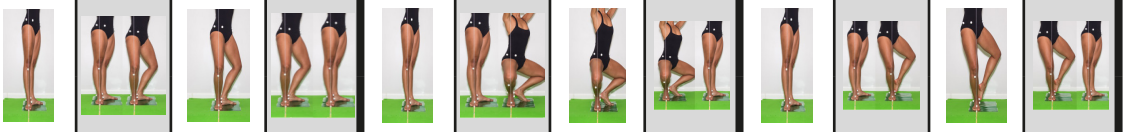
Annex A. Dynamic Evaluation Method of Lower Limbs Joint Alignment (MADAAMI-II) score sheet.

MADAAMI-II – Dynamic Evaluation Method of Lower Limbs Joint Alignment

Evaluator: | Mark "X" by criteria according to the feet position: **Self-reported turnout (SR)**; **120°**; and feet in **Parallel (//):**

Date: | DEMI-PLIÉ | GRAND PLIÉ | FONDU

Dancer:



Score	Evaluated steps: DEMI-PLIÉ, GRAND PLIÉ AND FONDU		STATIC PHASES	*MOTION PHASES*																																
			SK1			*DPD*			DP			*DPA*			SK2			*GPD*			GP			*GPA*			SK3			*FOD*			FO			*FOA*		
	Criterion: **FOOT ARCH**		SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//	SR	120	//
2	Unstable toward the 5th toe																																			
3	Stable																																			
1	Unstable toward the 1st toe																																			
	Criterion: **KNEE CENTER (static)**		SR	120	//				SR	120	//				SR	120	//				SR	120	//				SR	120	//				SR	120	//		
2	Above the 4th /5th toe or beyond the 5th toe																																			
3	Above the 2nd/3rd toes																																			
1	Above or beyond out the 1st toe (Femur internal rotation)																																			
	Criterion: **KNEE CENTER (dynamic) Subtitle: Internal Rotation (IR)**					SR	120	//				SR	120	//				SR	120	//				SR	120	//				SR	120	//				SR	120	//
4	Stable: starts and ends in the same position																																			
2	Unstable - starts with IR and ends above the 4th/5th toes or beyond the 5th toe																																			
3	Unstable - starts with IR and ends above the 2nd/3rd toes																																			
1	Unstable - starts with IR and ends above or beyond the 1st toe																																			
	Criterion: **PELVIS (static) Markers: Posterior(Post) and Anterior(Ant)**		SR	120	//			//	SR	120	//			//	SR	120	//			//	SR	120	//			//	SR	120	//			//	SR	120	//			//
2	PostMarker higher than AntMarker																																			
3	PostMarker aligned with AntMarker																																			
1	PostMarker lower than AntMarker																																			
	Criterion: **PELVIS (dynamic) Markers: Posterior(Post) and Anterior(Ant)**					SR	120					SR	120					SR	120					SR	120					SR	120					SR	120	
2	PostMarker unstable higher than AntMarker																																			
3	Stable: starts and ends in the same position																																			
1	PostMarker unstable lower than AntMarker																																			