ANALYSIS OF PROACTIVE, STATIC AND DYNAMIC UNIPEDAL BALANCE IN YOUNG GYMNASTS DURING ADOLESCENCE

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The aims of this study were to evaluate the effect of age in young acrobatic gymnasts on performance and asymmetry between lower limbs in proactive, static, and dynamic balance. 37 acrobatic gymnasts (31 females and 6 males) were divided in Early (EA, n=10), Middle (MA, n=16), and Late (LA, n=11) adolescence according to peak height velocity. Three types of unipedal balance tests were applied and normalised relative to participants height: Y-Balance Test, single leg stance test (centre of pressure excursions), time to stabilization after single leg landing test. EA gymnasts had higher values in the CoP excursion in static balance compared to MA and LA, and showed greater asymmetry in proactive balance between both legs compared to MA. These results must be considered to adapt the demands on static and proactive balance in gymnasts of early adolescence.

KEYWORDS: postural sway, asymmetry, age-related, Y-balance test, unipedal static test.

INTRODUCTION: Research on balance capacity has increased considerably in recent years. Sports such as acrobatic gymnastics that present high demands on static and dynamic balance, as well as constant stabilization on landings after defined acrobatic jumps, have received little attention.
Kiss et al. (2018) suggest, for balance assessment purposes, a battery of tests that include different types of balance performance. These include steady-state static balance (e.g., maintaining a stable and static position), dynamic steady-state balance (e.g., maintaining a stable position while changing body position), proactive balance (e.g., anticipation before potentially destabilizing voluntary movements) and reactive balance (i.e., compensation for an unanticipated postural alteration) (Shumway-Cook & Woollacott, 2016).
There are few works in acrobatic gymnastics that have focused on non-specific tasks (Gómez-Landero et al., 2021), and no studies have been found that have analysed other types of balances or possible asymmetries between lower limbs.
Chronological and maturation status has been suggested as essential factors to consider for better understand the physical performance development and fluctuations in injury risk of youth athletes (John et al., 2019; Moore et al., 2015). Children practicing acrobatic gymnastics start at a very early age, starting to compete in national championships before the age of 10. International age group categories can include gymnasts of very different ages within a wide range (e.g., ages 11-16, 12-18, 13-19). These ages are very sensitive to continuous changes due to growth and maturation. In fact, during natural bipedal stance with eyes open, many studies reported a decrease in postural sway with age, observing responses like those of adults from 13 years of age, although these results are not confirmed (Verbecque et al., 2016). Athletes within the early adolescent stage performed worse on the single-leg stance (modified Balance Error Scoring System) and showed greater dynamic balance asymmetry (Y-Balance Test) compared to their older counterparts (Breen et al., 2016). Significant age differences were found for associations between different types of balance in children compared to older adults (Kiss et al., 2018). In all these studies analysed with healthy individuals, asymmetry indices and proactive balance analysis were not reported as a measurement parameter.
Despite these evidence and the wide age ranges in competitive acrobatic gymnastics, possible differences in the types of balance between the stages of adolescence in gymnasts are unknown. This knowledge would allow the demands to be adapted to the maturation stage. Thus, the aims of this study were to evaluate the effect of age on performance (1) and the asymmetry (2) between lower limbs in proactive balance (single leg landing), static and dynamic in steady state (single-leg stance, and Y-balance test).

METHODS: In the period June-July 2023, n=37 acrobatic gymnasts (31 females and 6 males) were recruited from two different clubs. The subjects were divided into 3 groups according to the stage of adolescence early, middle, and late adolescence (EA=10, MA=16, LA=11), but grouped by the biological maturity, determined using age at peak height velocity (A-PHV, Moore et al., 2015). Their main characteristics are reported in Table 1. All of them had to be free of injuries in the lower limbs including vestibular or visual dysfunctions, they had to compete at the national level, with more than 4 years of experience, and training 12-15 hours per week. The study was carried out respecting the ethical principles for research with human beings expressed in the Declaration of Helsinki and was approved by the Ethics Commission for Research with Human Beings of the Pablo de Olavide University (code 23/3-2). Written informed consent was obtained from all participants and their parents after a detailed explanation of the purposes of the study and a description of the experimental methodology.

Chronological age, body height, leg length, and body weight were recorded for all participants. The Y-Balance Test (Y-BT) was used to measure dynamic steady-state unilateral balance in the anterior (YA), posteromedial (YPM), and posterolateral (YPL) directions. The length of the participants' lower extremity was measured as the distance from the anterior superior iliac spine to the centre of the medial malleolus. The greatest distance reached (cm) in each direction was normalized (% lower extremity length) and then averaged to establish a composite score (YCS). Side-to-side asymmetry (ASY) was calculated as the difference in absolute value between both limbs, in each direction and in the composite score, it was expressed as the absolute difference and relative to the length of the lower limb respectively (Muehlbauer et al., 2019).

Steady-state static balance was assessed with the static single leg stance test (SLS) maintained for 30 s (Gómez-Landero et al., 2021), using a force platform (Sensix®, Poitiers, France) using a force platform and obtaining the total length travelled by the centre of pressure (CoP) on the anteroposterior (AP) and mediolateral (ML) axis, and the mean speed of the CoP (SP). Three trials for each static posture were registered for each participant, at a sample frequency of 500 Hz. The trials were presented in random order. Given the differences in the height between groups, all CoP measurements were normalised relative to participants' height. The final performance values in the SLS test were obtained with the average between the parameters of both legs. Postural balance asymmetry between both legs were analysed using the symmetry index (SI, Anker et al., 2008) = $[(2 \times (|CoP_{RIGHT} - CoP_{LEFT}|))/(|CoP_{RIGHT} + CoP_{LEFT}|)] \times 100$.The SI is 0 if there is perfect symmetry. Positive SI values indicates higher asymmetry.

Time to stabilization after landing with a single-leg (SL-TTS) was assessed to measure unilateral proactive balance with both legs, following the proposal of by Byrne et al. (2021). Force platform was adjusted at a sample frequency of 1000 Hz. Individual body mass was measured in newtons by the force platform. Subjects were instructed to "step forward from a straight back leg, land and stick that landing position for a total of seven seconds". The total drop height was 20 cm from box to the platform. Three recorded trials were then performed with raw data exported for post testing analysis. Stability was defined as the point at which vertical GRF reached a level within 5% of body weight and remained within 5% of body weight for a subsequent second. The time point which corresponded with the first point at which vertical GRF crossed 10 N was accepted as initial contact time and was subtracted from the onset of stability to calculate SL-TTS (Byrne et al., 2021). The final performance values were obtained with the average between the values of both legs. Side-to-side asymmetry was calculated as the difference in absolute value between both limbs.

Means and standard deviations were calculated. Normal distribution was examined using Shapiro-Wilk tests. Analysis of variance (ANOVA) was performed to analyse balance performance and balance asymmetries between age groups. Post-hoc tests with Bonferroni-adjusted α were performed to analyse comparisons that were statistically significant. The significant alpha value was set at 0.05 for all statistics. The data analysis was conducted with JASP Statistics Software v. 0.18.0 (University of Amsterdam, https://jasp-stats.org/) and Microsoft Excel (2019). All CoP excursion parameters were performed with the software MATLAB.

RESULTS: Once all subjects were grouped by biological age (Moore et al., 2015), the 3 groups showed significant differences between themselves in all their general characteristics (Table 1), with the exception of Experience, which only showed differences between EA and MA. Maturational age groups only showed significant differences in the performance of static balance in steady state (Table 2), in all the parameters analysed (SP, F=12.268, η^2_p=0.432; ML, F=9.991, η^2_p=0.419; SP, F=8.907, η^2_p=0.408) with differences in EA-MA (p<0.01) and EA-LA (p<0.001). Only the asymmetry between both legs in proactive balance showed differences between EA-MA (F=4.555, η^2_p=0.215; p=0.014) (Table 2).

Table 1: Characteristics of the gymnasts by maturational age.

Characteristics	Early adolescence (-1.99 ≥ PHV ≤ 0.99)	Middle adolescence (1.00 ≥ PHV ≤ 2.99)	Late adolescence (3.00 ≥ PHV ≤ 5.00)
Age (years)	12.281 ± 2.007	14.969 ± 1.091	17.947 ± 1.792
Maturity offset (PHV)	-0.429 ± 1.090	1.983 ± 0.573	4.511 ± 1.109
Body weight (kg)	39.550 ± 8.536	50.144 ± 8.473	62.045 ± 7.043
Body height (cm)	146.200 ± 7.948	159.006 ± 6.194	166.909 ± 7.999
Experience (years)	6.400 ± 2.119	8.063 ± 2.016	9.182 ± 2.401

Values are mean ± SD. A-PHV = Age at peak height velocity

Table 2: Performance and asymmetries in proactive, static, and dynamic balance between groups.

Balance Measurements			Early adolescence	Middle adolescence	Late adolescence
Dynamic Balance	Performance	$Y_{Composite\ Score}$	93.845 ± 5.145	92.687 ± 5.195	89.471 ± 4.164
		$Y_{Anterior}$	68.711 ± 4.456	69.792 ± 6.328	66.482 ± 5.219
		$Y_{PosteroMedial}$	103.999 ± 5.283	103.283 ± 6.954	98.956 ± 7.127
		$Y_{PosteroLateral}$	108.824 ± 7.226	104.986 ± 5.731	102.975 ± 6.313
	Asymmetry	AS-$Y_{CompositeSc.}$	1.645 ± 1.558	1.841 ± 1.320	2.702 ± 2.000
		AS-$Y_{Anterior}$	1.633 ± 1.212	2.833 ± 1.994	2.273 ± 2.224
		AS-$Y_{PosteroMed.}$	2.383 ± 1.379	2.896 ± 2.218	2.606 ± 2.205
		AS-$Y_{PosteroLat.}$	2.250 ± 1.790	2.875 ± 1.930	4.470 ± 3.691
Static Balance	Perfor.	$SLS_{Anteroposterior}$	1.803 ± 0.519**	1.344 ± 0.252	1.092 ± 0.138^^^
		$SLS_{Mediolateral}$	2.560 ± 0.720**	1.904 ± 0.366	1.569 ± 0.261^^^
		SLS_{Speed}	0.131 ± 0.035**	0.100 ± 0.016	0.086 ± 0.011^^^
	Asym.	AS-$SLS_{Anterop.}$	1.931 ± 1.607	2.428 ± 1.857	1.609 ± 1.510
		AS-$SLS_{Mediolat.}$	4.446 ± 1.998	3.435 ± 2.179	4.706 ± 3.540
		AS-SLS_{Speed}	2.922 ± 2.148	3.041 ± 2.169	2.592 ± 1.983
Proac. Bal.	Perf.	SL_TTS	0.519 ± 0.167	0.591 ± 0.130	0.683 ± 0.440
	Asy.	ASY_SL_TTS	41.220 ± 34.929*	16.391 ± 8.621	27.214 ± 13.569

*Values are mean ± SD; *p<0.05 between Early-Middle; ** p<0.01 between Early-Middle; ^^^p<0.001between Early-Late. SLS: single leg stance*

DISCUSSION: In accordance with the objectives of the present work, the main findings showed that gymnasts in the early adolescence stage had higher CoP excursion in static balance compared to middle and late adolescence. Also, EA gymnasts showed greater asymmetry in proactive balance between both legs. All these results were obtained by normalizing the balance measurements by the height of the subjects (Gómez-Landero et al., 2021).

The greater postural sway in steady-state static balance observed in EA compared to MA and LA, coincides with the results of Gómez-Landero et al. (2021) with acrobatic gymnasts, as well as with other populations (Breen et al., 2016; Verbecque et al., 2016). These results may be since EA were closer to PHV at that stage, with consequent readjustments due to rapid changes in the human body (John et al., 2019). A general lack of maturation of the systems responsible for balance control could be another reason (Paillard, 2017) although these differences did not appear between the MA and LA stages.

There was no effect of age on dynamic balance performance, results consistent with other studies with soccer players (Breen et al., 2016). On the contrary, other studies showed shorter reach distances (Y-BT) in young soccer players compared to older (Muehlbauer et al., 2019). There were also no differences in proactive balance, probably because the chosen test was not challenging compared to other jump tests (Pau et al., 2019). Age also did not influence the asymmetries between both legs shown in static and dynamic balance, results contrary to Breen et al. (2016). Only asymmetry in proactive balance showed differences between EA-MA. The lack of injuries in the lower body of these gymnasts, and the specific daily training received to control programmed movements and receptions, could induce structural and functional adaptations in the postural control system (Paillard, 2017), and homogenize the performance and symmetry manifested between different age groups analysed. Given the different results obtained depending on the type of balance test analysed, it is advisable to integrate different tests to evaluate the balance capacity (Kiss et al., 2018).

CONCLUSION: Gymnasts in EA and closer to the PHV, showed higher CoP displacements in static balance and greater asymmetry in proactive balance, compared to MA and LA gymnasts. These results should be considered for adequate training programming, given the high demands on static and proactive balance in early adolescence gymnasts.

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