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Original Article

The effect of a proprioception and balance training program on balance and technical skills in youth female volleyball players

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Abstract:
A skilled control of postural stability is fundamental in many of the actions performed by volleyball athletes. The effectiveness in serving, forearm passing or setting the ball is affected by the athlete's ability to control their dynamic balance. When referring to team sports, earlier studies have shown that balance and proprioception training have the potential to induce performance enhancement in selected components of physical fitness and some technical skills but only few of them focus on the field of volleyball. Therefore, the purpose of this study is to investigate the effect of a balance and proprioception training program on dynamic balance and volleyball skills of female volleyball players aged 13-15 years. The sample is consisted by 18 participants who were divided into an experimental group (EG, N=10) and a control group (CG, N=8). In addition to volleyball training, the EG followed an 8-week proprioception and balance training program (3 times/week). Dynamic balance test results were obtained, and participants were rated for the movement outcome (performance score: PS) and movement form (Technique score: TS) of their motor tasks in volleyball skills. Two-factor ANOVA with repeated measurements on the second factor was used to examine the effects of groups and measurements and their interactions. The dynamic balance of the EG showed a significant improvement ($p = 0.009$). There was an increase in PS for serve ($p = 0.022$) and TS in forearm-passing ($p = 0.001$) for the EG, but not for the setting skill ($p > 0.05$). The study reveals that a targeted proprioception and balance training program can improve the dynamic balance of youth female volleyball players and contribute to the improvement of the movement form of the forearm passing and the movement outcome of the serve skill.
Key Words: **Dynamic balance, intervention program, developmental age, passing, serve, setting**

Introduction

In volleyball, players' performance is influenced by a series of physical and physiological parameters (Lidor & Ziv, 2010a, 2010b) and among them it seems that jumping ability and balance play a major role (Papageorgiou & Spitzley, 2002). All types of jumping are of great importance in both attack (Forthomme et al., 2005) and defence (Papageorgiou & Spitzley, 2002). However, during its execution, especially in the context of the offensive actions, balance affects the control of the body both during the approach to take-off and landing phase (Marquez et al., 2011). Furthermore, due to the cyclical nature of volleyball (Bergeles et al., 2009; Sotiropoulos et al., 2019), the rapid transition from jumping to each subsequent action, or vice versa, is only possible when the necessary balance is ensured during the landing or before the take-off. Moreover, a significant correlation has been discovered between balance and changing of direction (Sekulic et al., 2013).

Besides these, posture control is considered the basis for many other actions in volleyball. The ability to maintain a stable posture while making contact with the ball is rather important for the players' performance in the match (Kuczyński et al., 2009). The successful outcome of specific actions that are executed when contacting the floor, such as passing, defence-digging, setting and non-jumping-serving, depends on the players' ability to control their posture. Preventing loss of postural control is crucial since contacting the ball when in imbalance results in less accurate actions. This is because in such cases the central nervous system "favours" the restoration of postural control over the optimal execution of the skill (Borzucka et al., 2020a). Nevertheless, it seems that this selection process can be reversed to the extent that its negative impact on the efficiency of crucial actions is reduced. The "vehicle" for the transition to efficiency seems to be systematic long-term training that causes positive adjustments in posture control (Perrin et al., 1998). Moreover, the learning of a sport by itself, through long-term systematic training, improves both dynamic and static balance (Hain et al., 1999). This seems to occur due to the improvement of the speed of selection of the most critical -among the sensory- information, which suggests the most effective process of central identification and management of sensory information (Balter et al., 2004).

When referring to team sports, several researchers have studied the relationship between balance and performance and the effect of specially designed programs on it. However, most of them focus mainly on the field of football (Bekris et al., 2012; Gioftsidou et al., 2006), basketball (Chaouachi et al., 2014; Zacharakis et

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al., 2020) and handball (Holm et al., 2004). What is certain is the fact that each individual or team sport stimulates the sensory systems differently by methodizing appropriate adaptation strategies to the particular proprioception conditions that arise (Paillard, 2014). Although volleyball is one of the most popular sports in the world (Reeser & Bahr, 2003), the relevant studies are rather limited and mainly concern adult athletes (Borzucka et al., 2020b, 2020a; Brumitt et al., 2019; Kachanathu et al., 2014; Kuczyński et al., 2009; Pau et al., 2012). The research data obtained from these studies regarding the effect of proprioception and balance training on the performance of technical skills and the balance of volleyball athletes being at the developmental age could be considered insufficient. This fact, combined with the research-affirming view that proprioception and balance training contribute significantly to high performance in other team sports (Hrysomallis, 2011; Zacharakis et al., 2020), necessitates a thorough investigation of the issue for volleyball coaches of developmental ages.

Therefore, the purpose of the research was to study the effect of a proprioceptive and balance training program on the dynamic balance and basic volleyball skills in young female volleyball athletes, aged 13–15 years.

Materials & Methods

Participants

Eighteen female youth athletes (age = 14.2 ± 0.7 y, body mass = 59 ± 8.7 kg and height = 166.1 ± 6.6 cm) participated in this study. The athletes were separated into two groups, a control group (CG, N = 10) and an experimental group (EG, N = 8). The young athletes belonged to the same sports club and were trained by the same coach, attending the same volleyball training program on different days and hours. The intervention program lasted 8 weeks and included 3 sessions per week, performed after the regular volleyball training program of the participating athletes. A total of 24 training units were conducted. Each training unit comprised of 6 balance-proprioception drills and lasted 19-28 min. The program's duration and difficulty increased every two weeks for the athletes to smoothly adjust to it. All the athletes' parents were contacted to ask permission for their child's participation in the pre-, post-intervention measurements and their participation in the additional balance and proprioception training program. A total of 18 parents signed the informed consent form. This study was approved by the Ethical Committee of National and Kapodistrian University of Athens which is in accordance with the Helsinki Declaration.

Procedure

The anthropometric characteristics assessed were height, body mass and standing and seated height. The calculation of the length of the legs occurred from the subtraction of the sitting height from the standing height (cm). The time distance from the maximum rate of increase of height (Peak High Velocity, PHV) was calculated through the relation proposed by Mirwald et al. (2002) by using the standing and seated height, the body mass and the legs' length.

Standing and sitting height was measured using a SECA stadiometer (SECA, Hamburg, Germany) with an accuracy of 0.1 cm. The body mass was measured by using a precision scale (SECA 862) with an accuracy of 100 gr. For the evaluation of dynamic balance, the Lafayette Instrument 16030 Stability platform was used. The device was connected to an electronic timer to count the time that the flat platform, on which the test subject was standing, passed from, or remained in horizontal position.

The balance tests took place in a discrete room free from external distractions. Starting the assessment, the researcher positioned the athlete's feet following the appropriate alignments on the stability platform for the medial malleolus and the outside border of the heel. Afterwards, with the examiner's signal, the platform was set free, and the timing of the effort began with the electronic timer, which was connected to the platform and recorded the time the athlete stayed on or passed from the balance position to the nearest millisecond (msec). The balance position was set at a range of 5 degrees (5^o) from the horizontal line and there were 3 trials of 30 seconds (sec). Subjects were given the same duration as the rest between the trials. At the time of the test, all subjects wore sportswear and footwear. Before the start of the test, there was a demonstration by the examiner, as well as a test attempt. Performance was calculated as the average of the 2 best efforts.

The data of skills' evaluation were analyzed concerning movement outcome and movement form for basic volleyball skills such as overhead front setting, forearm passing and serve. Performance score (PS) was used as the measure of movement outcome. The performance of movement outcome for the skills of forearm passing and the overhead front setting was evaluated according to Bartlett et al. (1991), while the performance of movement outcome for the skill of serve was evaluated according to the tests proposed by American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD, 1969).

A six-point scale of focusing cue points according to Kernodle and Carlton (1992) was used as a measure of evaluation (Technique score: TS) of the movement form for each skill. These six points of focusing cues were chosen according to the suggestions of Kluka and Dunn (1996). In each of the aforementioned six focusing cues were awarded one point, so the skills that were executed perfectly in every evaluation aspect were awarded a score of 6. If the skill was executed in such a way that two of the cue points were correct, a score of two was awarded, while if the attempt was completely wrong, no score was awarded. Every athlete conducted a total of 10 trials; thus, everyone could amass a score between zero and sixty points. The subjects' movement form was evaluated by 2 judges who were experienced volleyball coaches with knowledge of the mechanics for each skill. Judges participated in a training session designed to familiarize themselves with the 6 point focusing cues of Kluka and Dunn, (1996). Judges were presented with a series of randomly selected test trials and differences in the scores given by the judges were discussed. After the training, judges evaluated 50 unseen videotaped trials 2 times, with a 10-days difference and the Cohen's kappa index was calculated for intra and inter-observer's reliability. The Cohen's kappa values were 0.96 and 0.95 for intra and inter-observer's reliability, respectively, which showed highly acceptable values (Altman, 1991), and, therefore, only one of the judges evaluated each of the test trials. Two high-definition cameras were used to record the trials, as mentioned in the respective literature (Barzouka et al., 2015).

Statistical Analysis

Data were analyzed in the SPSS v.23 statistical analysis suite, in the MS Windows© operating system. Descriptive statistics (Averages, Standard Deviations) was used for the anthropometric characteristics. A two-factor analysis (two-way ANOVA with repeated measures on the second factor) was used for the results of the tests in the dynamic balance and basic volleyball skills, [Groups (2) × Measurements (2)] to determine whether there are differences in the measurements (initial and final) of the groups (experimental and control) and to examine their interaction with the variables measured. The Sidak Post-Hoc test was used for the subsequent comparisons. Effect sizes (ES) based upon partial eta squared (η^2) were calculated to report on the magnitude of the effect with the following interpretation criteria adopted: .001- .05 = small effect, .06-.13 = medium effect, ≥.14 = large effect (Cohen, 1988). The significance level was set at $p < 0.05$.

Results

Height

There was no significant interaction found between the factors "group" and "measurements" from the analysis of variance [F $(_{1,16})$ = 0.266, p = 0.613]. On the contrary, a significant main effect of the factor "measurements" was found [F $(_{1,16})$ = 21.560, $p \leq 0.001$, $\eta^2 = 0.57$] given the change that occurred in the height of all athletes. It was found that after the end of the intervention program the amount increased by 0.5 ± 0.4% (Table 1).

Body mass

Regarding body mass, no significant interaction of the factors "group" and "measurements" was found [F $(_{1,16})$ = 0.855, p = 0.369]. In addition, no major effect of the "measurements" factor was found [F $(_{1,16})$ = 2.611, p = 0.126] neither of the "group" factor [F $(_{1,16})$ = 0.093, p = 0.765] (Table 1).

Peak height velocity index

The analysis of variance did not show a significant interaction of the factors "group" and "measurements" [F $(_{1,16})$ = 0.003, p = 0.958], neither a main effect of the factor "measurements" [F $(_{1,16})$ = 0.000, p = 0.995] and the "group" factor [F $(_{1,16})$ = 0.426, p = 0.523] (Table 1).

Table 1. Anthropometric measurements and peak height velocity of the young female volleyball players before and after (mean ± SD) the intervention program.

VARIABLE	**GROUP**	**MEASUREMENTS**	
		PRE	**POST**
HEIGHT (cm)	EG	165.8 ± 7.6	166.5 ± 7.7
	CG	166.5 ± 4.7	167.4 ± 4.8
BODY MASS (kg)	EG	59.3 ± 5.6	59.0 ± 5.0
	CG	58.6 ± 12.1	57.4 ± 10.2
PHV (years)	EG	1.83 ± 0.5	
	CG	2.0 ± 0.6	

EG: Experimental group, CG: Control group, PHV: Peak Height Velocity

Dynamic balance

Regarding the dynamic balance, a significant interaction of the factors "group" and "measurements" was found [F $(_{1,16})$ = 8.755, p = 0.009, $\eta^2 = 0.35$]. From the subsequent comparisons it was found that after the end of the program, the dynamic balance of the EG showed an increase both concerning the initial measurement (p = 0.01, $\eta^2 = 0.35$) by 73.1 ± 47.2%, and the corresponding value of the CG (p = 0.014, $\eta^2 = 0.32$). Also, a significant main effect of the factor "measurements" was found [F $(_{1,16})$ = 47.990, $p \leq 0.001$, $\eta^2 = 0,75$] given the change that occurred in the dynamic balance of all athletes. It was found that after the end of the intervention program the dynamic balance of all the volleyball players increased by 51.8 ± 45.5% (Figure 1). No significant main effect of the "group" factor was found [F $(_{1,16})$ = 2.111, p = 0.166].

Performance and Technique scores for the setting skill

Regarding the PS of the youth female volleyball players in the overhead setting skill, no significant interaction of the factors "group" and "measurements" was found [$F_{(1,16)}$ = 0.058, p = 0.812], neither at the main effect of the factor "measurements" [$F_{(1,16)}$ = 3.100, p = 0.097] and the "group" factor [$F_{(1,16)}$ = 0.244, p = 0.628].

Concerning the TS of the skill, no significant interaction of the factors "group" and "measurements" was found [$F_{(1,16)} = 0.020$, $p = 0.891$] as well as the main effect of the factor "group" [$F_{(1,16)} = 0.071$, $p = 0.793$]. However, a significant main effect of the "measurements" factor was found [$F_{(1,16)} = 42.087$, $p \leq 0.001$, $\eta^2 = 0.725$]. More specifically, after eight weeks of training all players improved TS by 28.7 ± 19.2% regarding their initial TS.

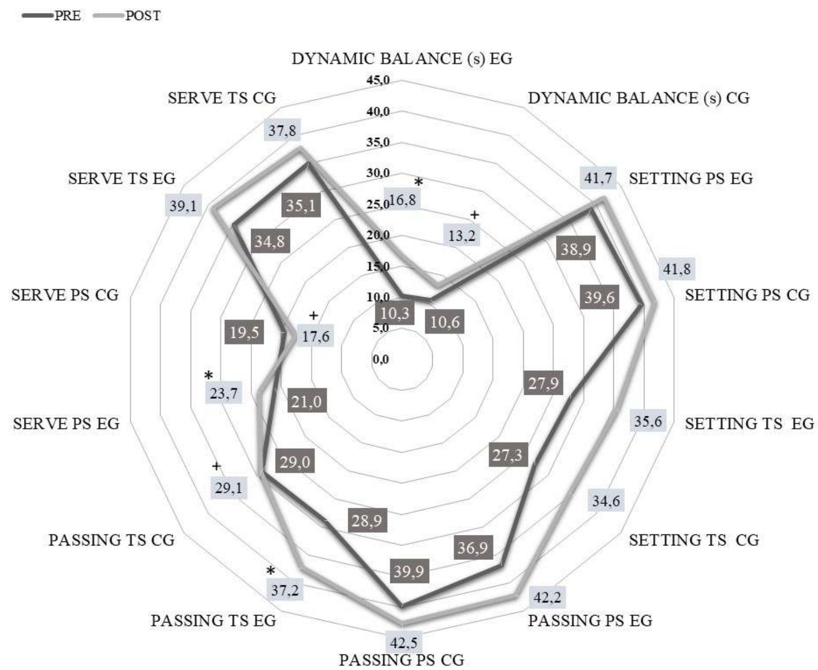

Figure 1. Dynamic balance, performance of movement outcome and movement form of the technical skills before and after 8 weeks of balance and proprioceptive training. EG: Experiment Group, CG: Control Group, PS: Performance Score, TS: Technique Score, $*p < 0.05$ significantly different from pre-intervention value, $^{+}p < 0.05$ significantly different from EG.

Performance and Technique scores for the forearm passing skill

The analysis of variance showed neither a significant interaction of the factors "group" and "measurements" [$F(_{1,16}) = 0.971$, $p = 0.339$], nor the main effect of the factor "group" [$F(_{1,16}) = 0.758$, $p = 0.06$]. However, a significant main effect of the "measurements" factor was found [$F(_{1,16}) = 8.524$, $p = 0.01$, $\eta^2 = 0.35$]. More specifically, after eight weeks of training all players improved in forearm passing PS by 28.7 ± 19.2% regarding their initial score.

Regarding the TS in forearm passing, a significant interaction of the factors "group" and "measurements" was found [$F(_{1,16}) = 18.790$, $p = 0.001$, $\eta^2 = 0.54$] as well as a significant main effect of the factor "measurements" [$F(_{1,16}) = 19.960$, $p \leq 0{,}001$, $\eta^2 = 0.56$]. It was found that after the end of the intervention program the TS of the EG improved both concerning the initial score ($p = 0.001$, $\eta^2 = 0.73$) by 34.5 ± 27.3%, and the corresponding score of the CG ($p = 0.001$, $\eta^2 = 0.64$, Table 2). In addition, it was found that in the same period the TS of all athletes improved by 19.2 ± 26.9%. No significant main effect of the "group" factor was found [$F(_{1,16}) = 4.325$, $p = 0.06$].

Performance and Technique scores for the float serve skill

As for the players' PS in the float serve, a significant interaction of the factors "team" and "measurements" was found [$F_{(1,16)} = 6.389$, $p = 0.022$, $\eta^2 = 0.285$]. It was found that after the end of the intervention program the PS of the EG improved both concerning its initial score ($p = 0.04$, $\eta^2 = 0.24$) by 16.2 ± 25.2%, and to the corresponding score of the CG ($p = 0.006$, $\eta^2 = 0.39$, Figure 1).

Regarding the TS of the skill, no significant interaction of the factors "group" and "measurements" was found [$F_{(1,16)} = 0.762$, $p = 0.396$] as well as the main effect of the factor "group" [$F_{(1,16)} = 0.038$, $p = 0.847$]. However, a significant main effect of the "measurements" factor was found [$F_{(1,16)} = 13.017$, $p = 0.002$, $\eta^2 = 0.449$]. More specifically, after eight weeks of training all players improved TS by 11.7 ± 13.5%. regarding their initial score.

Discussion

Volleyball is nowadays considered one of the most dynamic teams sports (Hasegawa et al., 2002). Athletes often must accurately perform individual skills in training and/or competition, in situations where their posture is not completely controlled (Papageorgiou & Spitzley, 2002). It has been discovered that balance can be positively affected by systematic training in many team sports (Agostini et al., 2013; Hrysomallis, 2011; Jakobsen et al., 2011; Kuczyński et al., 2009), causing adjustments that are proportional to the movements that predominate in each team sport (Paillard et al., 2007). On the other hand, special balance training seems to be affecting positively the control of posture but it is not yet clear whether it influences in the same way all the motor skills that are considered prerequisites in sports (Paillard, 2017).

In this study, the effect of a proprioception and balance training program on the balance and basic volleyball skills of young female volleyball players was examined. Regarding the balance, the results showed that the athletes who participated in the intervention program improved both in terms of the level they had before the program and in terms of the level that CG had at the respective time. This is partly in agreement with a previous study in which although the contents of the intervention program were similar, the static balance of volleyball athletes 13 ± 0.2 y was assessed with and without the involvement of the vision system (Pau et al., 2012). After 6 weeks of specific training and 18 training units, the researchers noticed an improvement in balance performance but only when the visual contribution was suppressed. Therefore, it was concluded that the intervention program reduced the dependency of balance control on the vision system and at the same time it enhanced the role of the proprioceptive system. In the present study, the researchers evaluated the ability to maintain and/or retrieve balance with the participation of the visual system, but under dynamic conditions in which the contribution of proprioception inputs is fundamental (Paillard & Noé, 2015). Possibly, therefore, the performance improvement of the athletes of EG is mainly due to adaptations that are located in the function of the somatosensory system.

Considering that although systematic volleyball training itself is a means of improving proprioception (Şahin et al., 2015) and of continuous practice of the visual system (Kioumourtzoglou et al., 1998) and consequently balance, the specific training in which the athletes of EG participated contributed to a significant additional improvement. Indeed, it was discovered that while the ability to control the posture of the athletes of CG in dynamic conditions showed a non-significant improvement by 25.2%, the corresponding ability of the athletes of EG improved significantly by 73.1% compared to its initial level. According to Aman et al. (2015), proprioceptive training can be very effective since active movement, balance exercises, somatosensory stimulation and somatosensory discrimination training all have been found to yield mean improvement rates of over 30%. Besides, proprioception plays an essential role in balance control (Han et al., 2015). These results confirm the findings of previous studies showing that combined basketball training with eight-week proprioception and balance training significantly improves static balance in adolescent female athletes (Mahmoud, 2011; Zacharakis et al., 2020).

The balance and proprioception training program of this study did not affect TS of the overhead setting more than the regular volleyball training. This could be considered quite unusual, due to the nature of this specific technical skill. Overhead setting is often performed while standing, jumping or rolling, a fact that indicates that its technique must adjust in every possible and unique trajectory of the ball (Selinger & Ackerman-Blount, 1986; Vujmilović & Karalic, 2013). However, the sensitivity of the test used in the study may not have allowed a clear assessment of the performance and technique of the subjects. Indeed, according to this, quite frequently settings that in real conditions could be effectively utilized by the attackers were evaluated with the lowest score of the relevant scale. On the other hand, although, as mentioned above, the nature of the skill presupposes its performance in different conditions, the quality of the technique was evaluated only in stable conditions. In addition to the sensitivity of the test, the complexity of the overhead setting (Selinger & Ackerman-Blount, 1986; Vujmilović & Karalic, 2013) may have required a longer training intervention than the one used in the present study.

Regarding the effect of balance training on the forearm pass, the present study showed that after the program there was an improvement in the TS of the skill. Although the initial hypothesis was that balance training would have a positive effect on both the PS and the TS, in the former of the parameters there was no significant change. Indeed, although the percentage change in EG was twice that of CG (5.3 vs. 2.6%), they did not differ significantly. This may be because balance enhancement may require a period of training longer than eight weeks. In a recent study, Zacharakis et al. (2020) found that a similar training protocol improved passing accuracy of youth male and female basketball players reinforcing previous findings (Bekris et al., 2012; Mahmoud, 2011). Moreover, they found that boys improved in fast shooting, in static and dynamic balance while girls only in dynamic balance. Regarding the TS of the skill, the EG was significantly improved both in terms of the initial score and the CG. Concerning forearm pass and especially before the contact with the ball, the feet are in quite an asymmetric position so that during the following contact the proper inclination of the surface of the hands is ensured and then move the arms under the ball (Selinger & Ackerman-Blount, 1986). Consequently, the efficiency of actions in which players are floor-based such as the forearm passing skill, depends on their ability to control their posture. This is because in the case of performing any technical skill without adequate postural stability, the central nervous system "favours" its recovery instead of the optimal execution (Borzucka et al., 2020b). So, it seems that in the case of the forearm pass there was an improvement of the movement form due to the balance enhancement within the time frames of the intervention program.

The above-mentioned improvement of the movement form was credited at both the EG and the CG performance for the skill of serve, as its execution technique was improved in all athletes by 11.7%. Although serve is the only "closed" skill in volleyball it seems that the slight forward movement of the body just before the contact of the palm of the hand with the ball (Selinger & Ackerman-Blount, 1986) but also any adjustments that had to be made in the case of any differentiated ball toss, were performed with greater accuracy by the volleyball players of EG, a fact that allowed them to be more efficient than their CG teammates. Although, volleyball training can cause positive adjustments in the perception of the angular position of the joints, proprioception and balance training is also an excellent method of improving it (Aman et al., 2015). So, it seems that the special training which the EG athletes underwent had a cumulative effect on the accuracy of the information regarding the position and movement of the limbs and the body in the space at any time (Paillard, 2017) and, consequently, the PS of the skill. Moreover, according to Gruber et al. (2007), the use of sensorimotor training seems to lead to adequate integration of various proprioceptive signals that contribute to adjusting the motor program to the demands required in distinct situations. Besides, previous studies have found that both kinesthetic ability (Pavlidou et al., 2006) and dynamic balance are highly correlated with the performance of certain technical skills in team sports (Zacharakis et al., 2020).

Conclusions

In conclusion, the results of the present study show that a targeted training program for proprioception and balance can significantly improve the dynamic balance of youth female volleyball players, while at the same time can contribute to the improvement of the movement form of the forearm passing and the movement outcome of the serve skill. It is therefore suggested that the coaches include, during the preparation of their athletes, specialized balance programs with contents related to the technical skills of volleyball. A further investigation of the effect of the duration and/or the training volume of a relevant training program on various parameters of the balance ability is also proposed. Additionally, for the understanding of the mechanisms through which proprioception and balance training programs improve dynamic balance control and technical skills' performance in young athletes of both genders supplementary research is needed.

Conflicts of interest: The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article

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