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ORIGINAL RESEARCH

The effect of warm-up on postural sway in the dominant and non-dominant leg

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Abstract

Although the chronic effects of a long-term warm-up program have been widely studied, to our knowledge, the number of studies examining the acute effects of a single warm-up session on inter-limb balance asymmetries in symmetrical sports such as cycling is limited. The aim of this study was to examine the effect of warm-up on postural sway in the dominant and non-dominant leg in male bicycle athletes. Sixteen healthy young male volunteers who engage in cycling sports participated in the study. The participants' age was determined as 15.50±1.15 years, body weight as 56.06±7.79 kg, height as 169.87±4.98 cm, and sports experience as 4.31±1.25 years. The postural control performance on the dominant and non-dominant leg of the athletes was evaluated on Biodex Balance System balance device platform for 20 seconds before and after a 10-minute warm-up exercise performed at a constant pedaling frequency of 80 RPM on a bicycle ergometer. In the comparison of the pre-test to post-test dominant leg Overall Sway Index (t=3.456; p=0.004), Anterior-Posterior (Z=-3.160; p=0.002) and Medial-Lateral (Z=-2.428; p=0.015) postural control scores of the participants, a significant decrease was found in the post-test. It was determined that warm-up exercise can only improve acute postural control in the dominant leg. The effects of the study can be extended to different sports branches with symmetrical features in order to obtain comparable results.

Keywords: Bicycle, dominant leg, non-dominant leg, postural sway.

Introduction

Warm-up is an application that increases the effectiveness of the somatosensory system by increasing the sensitivity of quantum, muscle, joint, and tendinous mechanoreceptors (Subaşı et al., 2008). It has been suggested that regular warm-up exercises performed before a competition or training session can be beneficial in improving subsequent sports performance (Aandal et al., 2018; Bishop, 2003). Warm-up exercises consist of low-intensity exercises that prepare the athlete for sports activities (Malone et al., 1996). The purpose of pre-exercise warm-up is to increase the temperature of muscles, blood, and connective tissue to enhance performance and prevent soft tissue injuries (Anderson & Burke, 1996). In addition, warm-up exercises have been found to positively affect the functioning of the muscle system by increasing cortical excitability and muscle fiber conduction time (Morris et al., 2020; Painter et al., 2020). It is believed that the effect accompanying warm-up is associated with the innervation of the muscle-tendon unit (Malone et al., 1996). Accordingly, warm-up is stated to improve both sensory and motor components of the postural control system (Paillard et al., 2018). It has been suggested that as a result of the increase in temperature, the neuromuscular system becomes more efficient, leading to an improvement in postural control (Bishop, 2003), and a 1 °C increase in body temperature can result in a 4% improvement in leg strength (Sargeant, 1987). Balance and strength exercises, as well as neuromuscular warm-up programs, can be

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implemented to chronically improve postural control and reduce neuromuscular interlimb asymmetries (Taube et al., 2008). Moreover, warm-up exercises that include moderately strenuous exercises have been shown to improve postural control (Paillard et al., 2018). Subaşı et al. (2008) found that 5- and 10-minute warm-up periods had positive effects on knee proprioception and balance.

Interlimb asymmetry, also known as bilateral difference or bilateral asymmetry, is defined as the differences in function or performance between the dominant and non-dominant limbs (Hodges et al., 2011). Long-term training in the same sport can lead to interlimb asymmetry (Gray et al., 2016; Hart et al., 2016). The existing literature highlights the importance of investigating the effect of warm-up practices on interlimb asymmetry due to the potential for asymmetry to become more pronounced with warm-up (Chen et al., 2021; Subaşı et al., 2008).

Several studies have investigated the effects of warm-up on various variables (flexibility asymmetry, agility, jumping, interlimb asymmetry and jumping asymmetry) in different sports disciplines (Chen et al., 2021; Pardos-Mainer et al., 2019; Yeung et al., 2021). However, little is known about the characteristics of warm-up that facilitate performance in cyclists and the leg asymmetry in balance control. The aim of this study was to examine the effect of warm-up on postural sway in the dominant and non-dominant leg in cyclists.

Methods

Participants

Sixteen healthy young male athletes who actively engage in cycling sports, with a mean age of 15.50±1.15 years, body weight of 56.06±7.79 kg, height of 169.87±4.98 cm, and sports experience of 4.31±1.25 years, voluntarily participated in the study. Participants who had been regularly involved in this symmetrical sports discipline (cycling) for at least 4 years and had at least 4 years of experience, and who had not experienced a significant lower extremity injury in the last 6 months were included. The exclusion criteria included any reported balance disorders or documented history of injury in the past two years. Participants were instructed to avoid intense activity, coffee, and alcohol 24 hours before the testing sessions. The tests were applied to all participants at the same times of the day (09:00-12:00).

The research was approved by the Non-Interventional Ethics Committee of the Faculty of Sports Sciences of Selcuk University (Decision Date: 04.10.2022, Number: 132). All participants were thoroughly informed about the procedures and written consent was obtained from them before participating in the study, in accordance with the Helsinki Declaration and approved by the Institutional Review Board. Measurements were carried out in the Performance Laboratory of the Faculty of Sports Sciences of Selcuk University.

Procedure

The participants' body weight was measured in kilograms and height in anatomical position, wearing sports clothing and without shoes. Information on the participants' sports experience was recorded. The design of the study was based on the study by Brighenti et al. (2022). Participants took part in laboratory tests twice, with a minimum of 48 hours (maximum of 96 hours) apart, before warm-up and after warm-up. All participants first went through a familiarization session where they were informed about all the procedures and performed a postural sway assessment to avoid any learning effect during the test sessions (Cug & Wikstrom, 2014).

During this familiarization session, participants were also instructed to pedal at a moderate intensity on a bicycle ergometer for 10 minutes (Monark Ergomedic 839 E; Monark, Varberg, Sweden) at a pedaling frequency of 80 revolutions per minute (RPM) and a rating perceived exertion (RPE) of 6 on the CR-10 Borg scale. Additionally, all participants wore a heart rate monitor before starting the warm-up exercises to monitor their heart rate (HR). HR values were recorded before and after warm-up. After warm-up, participants were asked to evaluate their perceived fatigue using the CR-10 Borg fatigue scale (Zhao et al., 2023).

Warm-Up Exercise

The warm-up exercise consisted of a 10-minute pedaling duration on a bicycle ergometer at a constant pedaling frequency of 80 RPM. Postural sway performance was evaluated immediately after the completion of the warm-up session.

Rating of Perceived Exertion (RPE)

The Rating of Perceived Exertion method was used to assess post-warm-up fatigue. RPE values were determined using the CR10 Borg Scale. RPE is divided into a scale of 1-10 based on individuals' cognitive habits (Williams et al., 1994). A score of "1" represents extremely easy, while a score of "10" indicates fatigue, with increasing difficulty as the score increases. The physiological response to perceived exertion primarily reflects breathing, especially during speaking. The description of physiological reaction is more objective and easier to define compared to subjective descriptions such as "hard" or "a bit difficult." Therefore, to enhance the accuracy of RPE assessment, a corresponding description of the physiological reaction was added for each rating (Zhao et al., 2023). Participants were asked to rate the overall experience of the warm-up session by answering the question, "How was the exercise?" immediately after a 10-minute warm-up session.

Postural Sway

For the assessment of postural sway performance, the Biodex Balance System (BBS, Biodex Medical Systems Inc, Shirley, NY) was used, which has been shown to be a reliable tool for evaluating dynamic postural performance in previous studies (Cachupe et al., 2001; Hinman, 2000). This system measures and records the ability to maintain their posture under dynamic stress. Higher scores obtained from the BBS indicate impaired balance performance. Participants were allowed to familiarize themselves with the measurement device through sufficient practice before the measurements were taken.

Participants were assessed in the postural sway test immediately after the warm-up session (approximately 1 minute later). The postural sway test was performed barefoot, wearing comfortable sportswear, separately on both right and left feet, with eyes open and the difficulty level of the measuring device set to "6". Each participant performed two trials, resulting in a total of two measurements. Anterior-Posterior (AP), Medial-Lateral (ML), and Overall Sway Index (OSI) scores were recorded for duration of 20 seconds. The postural sway performances of participants' dominant and non-dominant legs were measured in random order for each participant. To avoid any learning effect, measurements for the dominant leg were taken on one measurement day, while measurements for the non-dominant leg were taken on another measurement day.

Participants' dominant leg was determined based on their response to the question, "Which leg do you primarily use to kick a ball?" (Schneiders et al., 2010). During the test, participants were instructed to look at the screen, move the platform freely to determine their ideal foot position, and adjust the position of the supporting leg until they achieved a balanced position. Once the appropriate position was found, the platform was locked according to the coordinates of the participant's foot position, and the test was conducted. To eliminate the effect of the arms, participants were asked to place their hands on their opposite shoulders during the tests.

Data Analysis

The variables were presented as mean and standard deviation (SD). Normality was tested with the Shapiro Wilk test. According to the results of normality analysis, unpaired t-test and Mann Whitney U test were used to compare the groups, and paired t-test and Wilcoxon test were used to compare the pre-test and post-test. Statistical analysis was performed using SPSS 27. All tests were two-tailed, and the results were evaluated at a significance level of 0.05.

Results

The pretest and posttest OSI scores of the dominant and non-dominant legs are presented in Figure 1, AP scores in Figure 2 and ML scores in Figure 3.There was no statistically significant difference between the pre-test measurements of OSI (t=0.443; p=0.661), AP (U=114.00; p=0.596), and ML (U=117.50; p=0.690). Similarly, no significant differences were found in the post-test measurements of OSI (t=-0.262; p=0.795), AP (t=-0.345; p=0.733), and ML (U=123.50; p=0.864). Similar results were obtained in the comparison of the pretest-posttest OSI (U=96.50; p=0.234) difference scores of the participants in AP (U=98.00; p=0.255) and ML (t=0.191; p=0.850).

Table 1
Participants' demographic characteristics.

Variables	n	Mean	SD	Minimum	Maksimum
Age (years)	16	15.50	1.15	14.00	17.00
Height (cm)	16	169.87	4.98	162.00	178.00
Body weight (kg)	16	56.06	7.79	45.00	71.00
Sports Experience (year)	16	4.31	1.25	2.00	7.00
RPE (point)	16	10.62	1.25	7.00	15.00

RPE: Rate of Perceived Exertion.

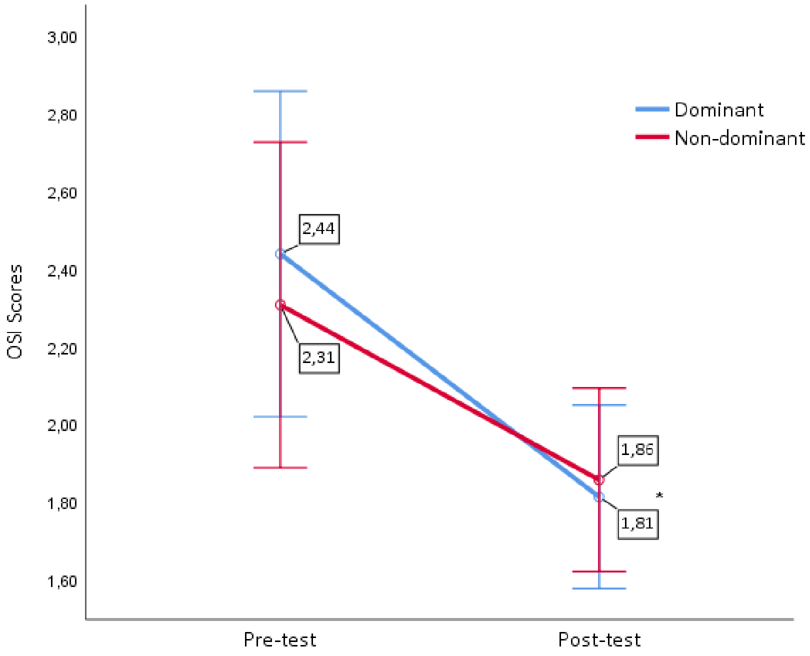

Figure 1. Pre and post test OSI scores in dominant and nondomianant legs. OSI: Overall stability index; *: Statistically lower than pretest (p<0.05). Error bars indicate standart error of the mean.

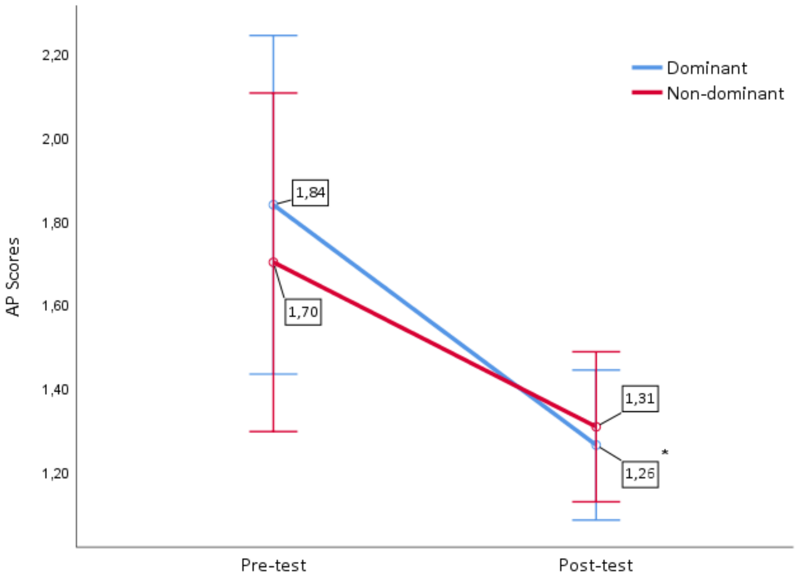

Figure 2. Pre and post test AP scores in dominant and nondomianant legs. AP: Anterior-posterir; * Statistically lower than pretest (p<0.05). Error bars indicate standart error of the mean.

In the comparison of the pre-test to post-test dominant leg postural sway scores, a significant decrease was found in OSI (t=3.456; p=0.004), AP (Z=-3.160; p=0.002), and ML (Z=-2.428; p=0.015) scores after the warming up (p<0.05). However, no statistical significance was detected in the pre-test to post-test non-dominant leg OSI (t=2.065; p=0.057), AP (Z=-1.424; p=0.154), and ML (Z=-1.612; p=0.107) scores (p>0.05).

There were no significant differences in postural sway scores between the dominant and non-dominant legs during the pre-tests and post-tests. Acute changes in postural sway were observed in the dominant leg following warm-up exercises, while no significant changes were detected in the non-dominant leg.

As shown Figure 4, the difference scores of dominanat and non-dominant leg did not differ in OSI (U=96.500; p= 0.234), AP (U= 98.000; p= 0.255) and ML (t= 0.191; p= 0.850).

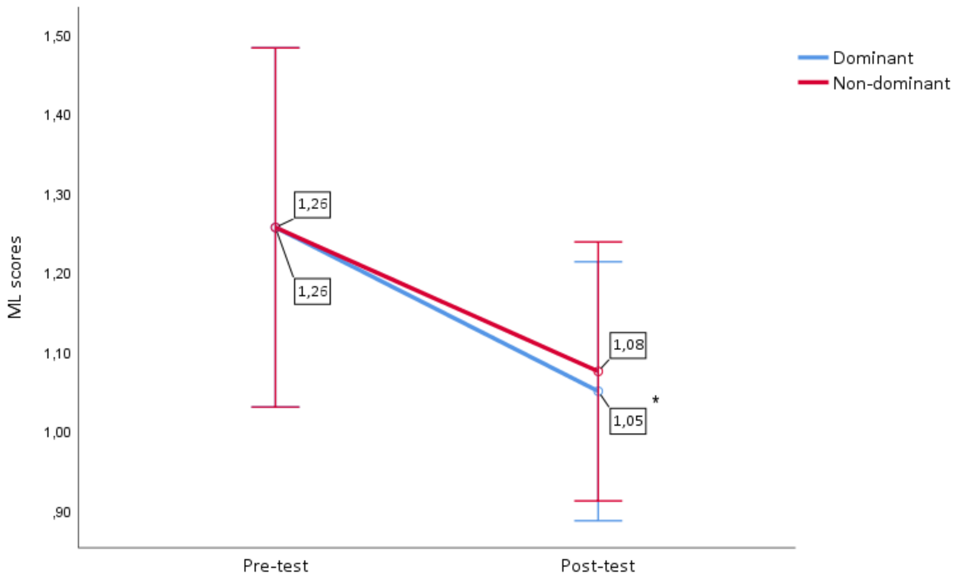

Figure 3. Pre and post test ML scores in dominant and nondomianant legs. ML: Medio-lateral; * Statistically lower than pretest (p<0.05). Error bars indicate standart error of the mean.

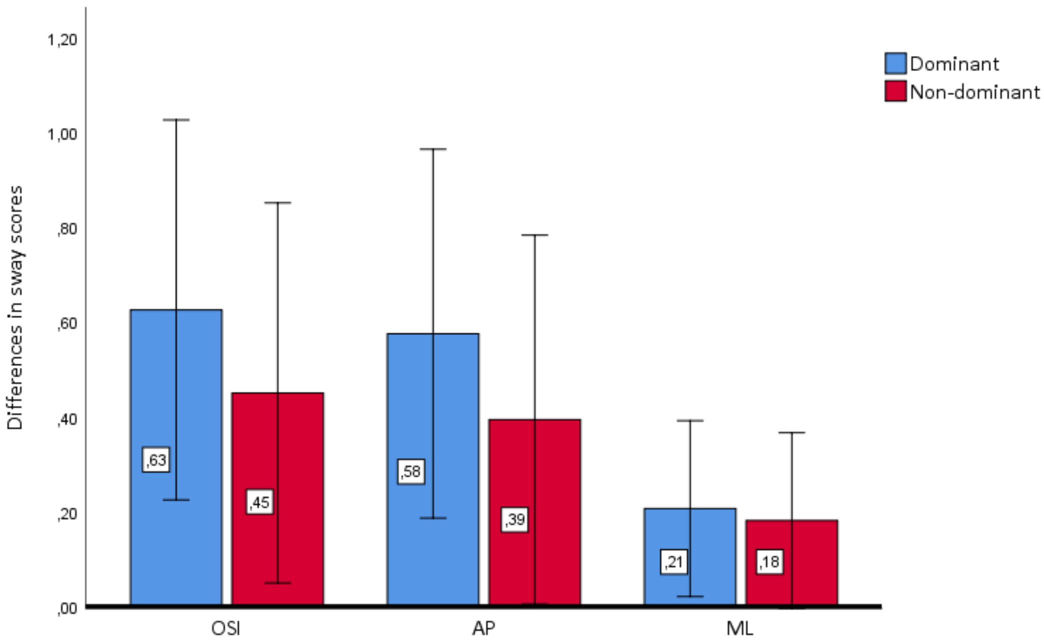

Figure 4. Differences between pre test and post test in postural sway scores of dominant and nondomianant legs. OSI: Overall stability index; AP: Anterior-posterior; ML: Medio-lateral. Error bars indicate standart error of the mean.

Discussion

Moderate-intensity warm-up exercises in young cyclists acutely affected interlimb (dominant and non-dominant leg) balance symmetries. A significant decrease was observed in the postural control scores of the dominant leg when comparing the participants' scores between the pre-test and post-test. It was determined that warm-up exercises improved acute postural control only in the dominant leg.

In a recent study, warm-up exercises improved acute balance control only in the dominant leg, without significantly reducing interlimb balance asymmetries after a 20-minute rest. This effect was more characteristic of participants with asymmetric sport experience. These results confirm previous findings that the dominant leg is more sensitive to physiological changes and reveal that differences in balance control between the legs, particularly in a specific physiological condition (post-warm-up condition), occur in subjects with asymmetric sport experience (Brighenti et al., 2022).

Training interventions can be implemented to chronically improve balance control and reduce neuromuscular interlimb asymmetries (Madruga-Parera et al., 2020; Taube et al., 2008). However, warm-up routines involving moderately strenuous exercises can acutely improve postural control to enhance motor performance (Paillard et al., 2018). The effects of the FIFA 11+ program compared to a standard warm-up on physical performance and interlimb asymmetry were evaluated in adolescent female soccer players. The FIFA 11+ program resulted in a decrease in lower limb asymmetry in unilateral hopping, dynamic postural control, and various tests in adolescent female soccer players. Significant improvements in postural control values were observed in both groups (Pardos-Mainer et al., 2019). Some studies have reported differences between the left and right legs while participants stand in a unilateral stance. This reflects a bilateral asymmetry in the control of balance between the dominant and non-dominant legs (Barone et al., 2010; Promsri et al., 2020). Postural control tends to change following a few minutes of recovery or stretching after the end of the dynamic phase of a warm-up routine, leading to better postural control (Subasi et al., 2008; Paillard et al., 2018).

The dominant leg, especially in individuals engaged in asymmetric sports, will be more sensitive than the non-dominant leg to exhausting exercises that lead to a decrease in maximum force or power production by muscles (Guan et al., 2021; Penedo et al., 2021). The improvement in postural control performance of the dominant leg after warm-up observed in this study confirms this information.

Brighenti et al. (2022) reported that giving a 20-minute rest period after warm-up could improve balance control in the dominant leg and therefore indicated the need for a short rest period after the warm-up routine to optimize postural control. They stated that this beneficial effect of warm-up on the dominant leg is more pronounced in asymmetrical sports athletes. However, our study suggests that postural control scores in the dominant leg of cyclists show improvement after warm-up, indicating a similar effect may be present in symmetrical sports.

When the dominant leg is used, the non-dominant leg is used to support the athlete's body weight (Matsuda et al., 2008). Therefore, we expected to observe no differences in postural control between dominant and non-dominant legs in cyclists. However, in the current study, there was no difference in the non-dominant leg after warming up. One study compared the balance abilities of football players, basketball players, swimmers, and non-athletes during a static single-leg stance. There were no significant differences in body sway between standing on the dominant leg and standing on the non-dominant leg in all four groups of participants. Similar results were obtained in basketball players and swimmers who use both legs equally, that is, in sports branches that are symmetrical (Matsuda et al., 2008).

Regular practice of football or other asymmetric sports such as volleyball, handball and tennis can cause specific postural adaptations that may explain why the non-dominant leg shows better postural control than the dominant leg (Marchetti et al., 2014).

The results of our study showed that warm-up exercises did not have an effect on the postural control performance of the non-dominant leg. The level of expertise of the athletes is also likely to emphasize the difference between the dominant and non-dominant leg (Kilroy et al., 2016). Promsri et al. (2020) showed that postural movements are better controlled with more regular controller interventions in the non-dominant leg compared to the dominant leg, suggesting a different sensorimotor control depending on leg dominance.

Paillard (2017) pointed out that the high level of motor skills associated with the high weekly training intensity may contribute to a high level of specialization in the motor skills of athletes and the differentiation of postural skills between the dominant and non-dominant leg. However, no postural differences were reported between the dominant leg and the non-dominant leg in professional football players (Debski et al., 2017; Pau et al., 2014).

Paillard and Noé (2020) explained this situation by saying that the level of expertise is not a determining factor or that the difference between the two legs remains relatively low and includes other factors. Additionally, some authors have suggested that cerebral hemisphere specialization should not be understood as the absolute superiority of the right cerebral hemisphere over the left cerebral hemisphere for postural control. However, they stated that the functional superiority of the right hemisphere in processing functions related to postural control leads to a greater proportional effect on the stabilization and recovery of balance. Therefore, it will affect the postural control mechanism of the dominant leg (Yoshida et al., 2014).

Conclusion

The results of the study revealed that there was no difference in postural sway scores between the dominant and non-dominant legs during pre-tests and post-tests. While no effect was observed on the non-dominant leg after the warm-up intervention, a significant change was detected in the dominant leg. This finding demonstrates that warm-up is more effective on the dominant leg. In order to obtain comparable results, it is recommended to extend the effects of the study to different sports branches that have symmetrical characteristics.

Authors' Contribution

Study Design: YK, AA, ÖÇ, AE; MMI; Data Collection: YK, AA, ÖÇ, AE; Statistical Analysis: AA; Manuscript Preparation: YK; Funds Collection: AA, ÖÇ.

Ethical Approval

The research was approved by the Non-Interventional Ethics Committee of the Faculty of Sports Sciences of Selcuk University (Decision Date: 04.10.2022, Number: 136). It was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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