Research Paper

Visual Reliance to Restore Balance in Healthy, Prone to Injury, Coper, and Chronic Ankle Instability Individuals

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ABSTRACT

Objectives: The visual system plays a crucial role in controlling the posture of individuals by updating information on the positions and movements that different parts of the body perform. This study aimed to investigate and compare the role of vision in balance recovery strategies between healthy, prone to injury, Coper, and chronic ankle instability (CAI).

Methods: The current research was of an applied and comparative type, which was conducted on male athletes in the age group of 18 to 30 years. Subjects were divided purposefully into four groups including CAI (n=15), Coper (n=15), prone to ankle injury (n=15), and healthy group (n=15). In this study, treadmills were used to create disturbance in the subjects' postures in both anterior and posterior directions, and Kinovea software to record kinematic information about subjects during sudden disturbances. Paired t-test was used to compare the scores of the subjects in open and closed eyes.

Results: The results of the paired t-test showed that in the variables of ankle oscillations, hip oscillations, and the ratio of the hip to ankle oscillations in both anterior and posterior disturbances in the groups of CAI, Coper, prone to injury, and healthy, there was a significant difference between open eyes (P=0.001) and closed eyes (P=0.001). The order of most fluctuations in all variables was from CAI group to Coper, prone to injury, and healthy, indicating the greater effectiveness of balance recovery strategies by eliminating visual feedback in the CAI group.

Discussion: To summarize the research findings, compared with uninjured and Coper participants, those with CAI had less balance and more functional limitations. Therefore, in training programs for ankle sprain rehabilitation, special attention should be paid to balance recovery strategies and the role of visual feedback to control posture.

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Highlights

- Ankle sprain is one of the most common injuries to the musculoskeletal system, especially among active people.

- Research findings showed that compared to uninjured and impaired participants, individuals with chronic ankle instability (CAI) had less balance and more functional limitations.

- By removing visual feedback in all groups (CAI, Coper, prone, and healthy), the amount of ankle sways, hip sways, and the ratio of the hip to ankle sways in both anterior and posterior disturbance was more than the state of open eyes.

- Rehabilitation should pay attention to balance recovery strategies and factors affecting it in athletes with ankle injuries.

Plain Language Summary

The sense of vision plays a direct and essential role in balancing, with the moment-to-moment information it gives to the nervous system from the surrounding environment. Any reduced or impairment in vision leads to alternations in motor function and balance. The lack of vision, in addition to making changes in postural control, results in increased social dependence, restricted daily activities, reduced self-confidence, and increased risk of falls. Controlling balance depends on the integration of afferent information from the vestibular, visual, and sensory systems. When the activity of one of the systems involved in postural control is reduced or completely lost, decreased performance occurs in other mechanisms involved in postural control. The importance of examining visual dependence and recovery of balance strategy in different ranges of ankle injuries has not been studied so far. The present research revealed that removing visual feedback in all groups (chronic ankle instability, Coper, prone to ankle injury, and healthy), the amount of ankle sways, hip sways, and the ratio of hip to ankle sways in both anterior and posterior disturbance was more than the state of open eyes. Ankle injuries can play an important role in transferring balance recovery strategies from the ankle to the hip and provide the basis for reducing the balance ability in athletes. Therefore, special attention should be paid to balance recovery strategies and factors affecting it in athletes with ankle injuries to control posture in training plans for ankle sprain rehabilitation.

Introduction

It seems that the ability to control posture during static and dynamic tasks is always achieved through precise and fast sensory mechanisms that can produce corrective responses based on integrated information from the visual, vestibular, and proprioceptive systems [1]. In this regard, it has been reported that the overall goal of balanced standing can be defined as the integration of sensory and motor information to maintain the body's center of gravity with the least possible movements within the support surface [2]. Meanwhile, there are various postural strategies to achieve this goal. Postural strategies are special patterns of muscle activity, joint torques, and body movements that are stimulated through balance disturbances [3]. These strategies help to prevent the body's center of gravity from leaving the support surface, prevent people from falling, and restore a stable posture [4]. Various factors can play a role in choosing each of these strategies, including the amount of available sensory information, the range of the level of reliance, musculoskeletal indicators, and degree of movement [5]. Among the available sensory information, the role of visual information is important as the most important sensory source involved in balance. The vision system plays a decisive role in establishing the control of posture through the nervous system and updating information on the positions and movements performed by different parts of the body [6]. Although other senses also provide valuable information, in the end, it is visual information that provides the most reliable and detailed information about the surrounding environment [7]. In this regard, the results of previous reports indicate that the amount of postural fluctuations in people increases by 20-70% when their visual information is removed compared to when their eyes are open [8]. Therefore, any disorder in the vision system can affect vision perception and diagnosis, control of balance, and the choice of balance strategy [9].

Based on previous research, it has been determined that each of the strategies used to restore balance has a specific pattern of synergistic muscle activity. These movement patterns are related to compensatory mechanisms that are used in both forward and backward movements as anticipatory behavior to maintain and restore the balance used [10]. In general, three categories of movement patterns including ankle joint strategy, hip joint strategy, and stepping strategy have been identified to maintain the balance of the body while standing on the legs [11]. In previous research, increased postural sway has been reported as a risk factor for lower limb injuries such as ankle functional instability and anterior cruciate ligament injury. Some sports injuries are related to poor posture control and lack of balance, such as sprains and ankle sprains [12].

The International Ankle Consortium (IAC) pathology defines the remaining symptoms after an obvious ankle sprain as chronic ankle instability (CAI) [13]. Approximately 20% to 40% of individuals who sustain an ankle sprain may develop CAI, characterized by recurrent instability episodes, mechanical laxity, functional instability, arthrokinematic changes, or balance deficits [14]. People with ankle sprains who have no recurrent or unstable symptoms and engage in high-level activities without recurrent injury or loss of function (turning, jumping, etc.) return to sport and process like non-injured people, known as "Coper" [15]. CAI usually occurs after lateral ankle sprains; differences in movement patterns between subtypes of ankle instability have not yet been identified. People with mechanically and functionally unstable ankles show different kinematics and kinetics than Copers. Coper people adapt well to an ankle injury and do not have the symptoms and subsequent problems of CAI [16].

Also, people with ankle instability have poor posture control and balance, and increased posture sways increase the risk of sprains and ankle injuries [17]. The high prevalence of sprained ankles, the related financial costs, and the potential for chronic negative consequences have attracted the attention of researchers to research to identify and control the factors influencing this injury. Lack of postural control is one of the factors that may put the athlete at risk of re-injury of the ankle sprain [18]. In this regard, there have been recent debates in the research regarding the importance of assessing dynamic posture control and its relationship with ankle sprain injury. Noronha et al. (2013) showed that the poor performance of people in dynamic balance (Y test) puts 48% more of them at risk of developing ankle sprains [19]. In people with CAI, deficits in postural control strategies of standing on one leg are observed [20], which may be the result of changes in nerve signals after the first ankle injury. This theory has been investigated in past research between people with a history of ankle injury and healthy people [21]. Kinetic and kinematic measurements of standing on one leg with eyes open and closed have been made between people with a history of the first ankle injury in the acute stage and healthy people [22]. It has also been reported that the performance of the Coper group in the control posture strategy in standing on one leg with eyes closed and open is similar to healthy people [20]. This model of studies is not ideal and suitable for determining why some people with external ankle sprain injuries do not recover. A more appropriate comparison is to use people who have experienced previous injury but have not experienced chronic instability (Coper) and people who are prone to injury. For example, it has been determined that the comparison of single-leg balance in athletes with CAI was different from that of Coper and healthy individuals [23], and poor posture control was evident in athletes with CAI. It has also been reported that muscle activity for balancing strategies was reduced between athletes with CAI with Coper and healthy athletes during single-leg standing [24].

There are many reports about the role of vision in the ability to control the posture of athletes indicating the importance of visual information in this field [22, 25, 26]. However, none of these reports has investigated the role of visual information in the strategies of restoring balance in different ranges of people with ankle injuries. There is still uncertainty about whether balance recovery strategies are affected by the presence or absence of visual information in people with ankle injuries or not. Studying the effectiveness of each of the sensory inputs on maintaining balance is important because physiotherapists and sports coaches use it as a main strategy in designing treatment protocols to increase people's balance. Considering that the importance of the role of the visual system in the balance recovery strategies in the condition of disturbance in athletes with ankle injuries has not been studied so far, this research aims to investigate and compare the role of vision in the balance recovery strategies between healthy, prone to injury, Coper, and CAI individuals.

Materials and Methods

Participants: The current study was an applied and comparative study, which had a four-group design with one measurement stage. To reduce the measurement error in the selection of three groups of athletes and due to the limitation caused by COVID-19 and limited access to female athletes, only male subjects were included in the study. The statistical population included all male athletes in one of the sports fields of volleyball, basketball, and handball with at least three years of sports experience. Regarding the statistical sample size of previous studies, 60 sportsmen were selected to participate in the research after obtaining their consent. It should be noted that the eligible subjects, according to the criteria for entering the research, were non-randomly divided into 4 groups of CAI (n=15), Coper (n=15), prone to ankle injury (n=15), and healthy group (n=15) (Table 1).

The research criteria include male athletes with an age range of 18-30 years who have at least three years of continuous participation in sports that mainly involve jumping and landing (volleyball, basketball, and handball). To confirm people with CAI (functional and mechanical instability), according to the criteria of the IAC statement [13], the athletes needed to have: 1) A history of at least 1 major ankle sprain, 2) A history of at least 1 major ankle sprain in the last 12 months, at least one external sprain injury in the ankle that requires some protection, inability to bear weight along with immobility, 3) And in the last 6 months, at least have the feeling of ankle instability or the feeling of joint emptying during daily activities or sports twice. Also, Coper's group after the first injury should not be re-injured and at least have a feeling of instability and emptying of the wrist [27]. Also, having a score >22 as Coper and having a score <22 in the CAI group, in the joint functional assessment tool (AJFAT) [28], having a score >24 as Coper, and having a score <24 as instability group in the functional ankle instability questionnaire (CAIT) [29], getting a score less than 94% of leg length in the normalized scores of the overall score of the Y test in the group prone to ankle injury [30] and not having a history of aspirin outliers in healthy athletes were used to group subjects. Other criteria for entering the study include voluntary participation in the study, not having a history of fracture or surgery of the joints of the lower limbs, any visible abnormality in the lower limbs, any sedative medication within 72 hours before the test, not having a history of systemic diseases such as rheumatism and diabetes, not having a history of vestibular system disorders (balance problems), and not having vision disorders based on the medical report [31, 32]. Also, severe pain and inability to perform the research tests, not completing the research, not attending the scheduled meetings, not wanting to continue the research, and withdrawing from the research were considered as criteria for exiting the research.

Instruments

In this research, a variety of instruments were used to control visual feedback including a demographic information questionnaire, research results, and information registration form; individual and informed consent form; and a star dynamic balance test (Y) to identify people at risk of ankle sprain injury (intra-examiner reliability coefficient=0.91, inter-examiner reliability=0.99 [30]); AJFAT questionnaire (internal correlation coefficient=0.94 [28]), and CAIT questionnaire (validity=0.80, reliability=0.96 [33]) to identify people with CAI injury and Coper people, treadmill to create disturbances in subjects' posture in both anterior and posterior directions, Kinovea software to record information, kinematics related to subjects during the sudden disturbance, skin markers, a digital camera, and tripod to take pictures of joint angles in recording subjects' kinematic information, and blindfolds.

Procedure

For the initial selection of the subjects, before providing the consent form and personal information to the subjects, the level of activity, history of ankle injury, and their willingness to participate in the research were confirmed orally and through an interview. In the following stage, after the necessary explanations regarding the goals and benefits of the current research, the subjects, selected based on the criteria for entering the research, completed the consent form and the personal information questionnaire. Before starting the measurements, an effort was made to explain the objectives of the research, the steps of the work, and how to conduct the tests in general for the participants and to ensure that their personal information and files are completely confidential and only available to the examiner. At the same time, any of the subjects could withdraw from the cooperation at any stage of the research. In this research, as much as possible, the subjects were tried to be homogeneous in terms of age, height, weight, and body mass index, so that the results of the research are not affected by these factors. Finally, 60 qualified people based on the criteria for entering the study were non-randomly divided into four groups including CAI (n=15), Coper (n=15), prone to ankle injury (n=15), and healthy group (n=15).

In the present study, Kinovea motion analysis software, version 0.8.25 was used to accurately record kinematic information related to strategies for restoring balance during a sudden disturbance [34]. A treadmill was used to disturb posture in both anterior and posterior directions. In this way, a space with dimensions of 2×2×2

Table 1. Descriptive and demographic information of the subjects in different groups

Groups	Age (y)	Height (cm)	Weight (kg)	BMI
CAI	24.93±2.43	181.80±5.22	78.60±2.79	21.63±1.05
Coper	25.26±2.52	179.60±3.75	79.13±3.68	22.03±1.02
Prone to AI	24.46±2.82	180.53±3.92	78±6.31	21.60±1.71
Healthy	25.46±2.03	181.46±2.69	79.66±3.97	21.95±1.10
F	0.465	0.919	0.398	0.451
P	0.780	0.438	0.755	0.718

Abbreviations: CAI: Chronic ankle instability; AI: Ankle instability; BMI: Body mass index.

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meters was defined for performing movements, and the treadmill was placed in the central part of this area. To recognize the subject's movement by the cameras, before the start of the experiment, five spherical light-reflecting markers with a diameter of 2 cm were installed on the right side of each subject's body. Placement of the markers was: anterior superior iliac spine (ASIS), greater trochanter of the femur, external epicondyle of the femur, external ankle, and head of the fifth metatarsal bone (Figure 1). The ankle joint was considered as the angle between the foot and the leg, while the hip joint was considered as the angle created between the thigh and the pelvis [35]. The subjects were asked to face the treadmill screen once and then back to the screen and maintain their upright position against sudden acceleration, to determine the direction of movement and create anterior and posterior perturbations. It should be mentioned that to control visual feedback, the measurements were done once with eyes closed and once with eyes open. In the future, without giving knowledge to the subject, the tape recorder started to move suddenly, and disturbance was applied to the person's posture in the anterior-posterior or posterior direction. The subjects were asked to deal with the disturbance without taking a step, and if the legs were moved, the movement was repeated. It should be noted that the safety of the subjects was provided by the support provided by the examiner. The initial movement speed of the treadmill was set to 1.1 m/s for all subjects based on the pilot plan, which caused the treadmill to move 40 cm. By starting the movement, the camera recorded the range of motion of the joints and body parts marked with markers for 5 seconds [36]. Each subject performed the movement three times (with eyes open and closed), and to check the variables, the average of three repetitions was evaluated. A time interval of 30 seconds was considered as rest time between each repetition. To calculate the kinematic changes in the ankle and thigh joints, the information was analyzed in Kinovea software. To examine the superiority of each of the ankle and thigh strategies in this research, the division of the hip joint sways by the ankle joint sways was used, which means that the larger this ratio is, the greater the reliance on the thigh strategy, and the smaller the ratio, the more use of ankle strategy to restore balance [35]. Finally, the recorded information was extracted from the software as an Excel file and entered into SPSS software.

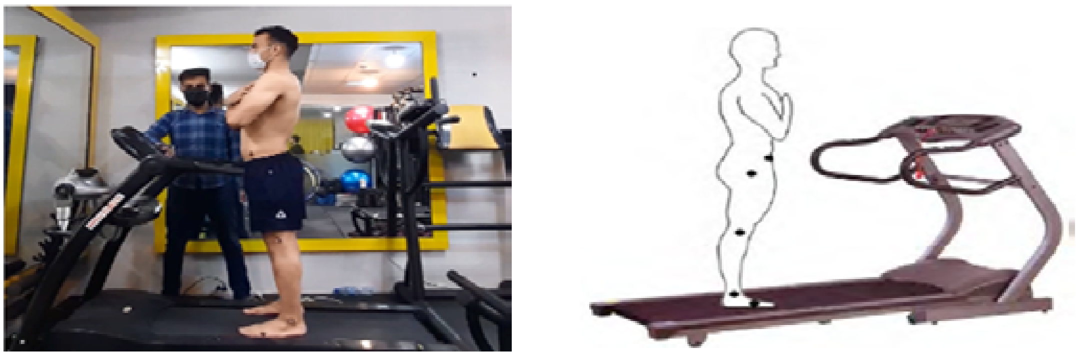

Figure 1. Position on a treadmill and reflex markers on the body

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Table 2. The results of the paired t-test in the open and closed eye conditions of the CAI group

Variables	Direction of Movement	Eye Condition	Mean±SD	Grade Difference (Grade)	df	P
Hip strategy	Anterior perturbation	Open eyes Closed eyes	6±0.81 8.50±1.10	2.68	14	0.001
	Posterior perturbation	Open eyes Closed eyes	7.45±1.06 9.93±1.03	2.48	14	0.001
Ankle strategy	Anterior perturbation	Open eyes Closed eyes	4.69±0.95 6.69±1.04	2	14	0.001
	Posterior perturbation	Open eyes Closed eyes	5.43±0.71 6.83±0.81	1.4	14	0.007
Hip strategy	Anterior perturbation	Open eyes Closed eyes	1.27±0.21 1.51±0.29	0.24	14	0.001
Ankle strategy	Posterior perturbation	Open eyes Closed eyes	1.22±0.22 1.48±0.29	0.26	14	0.001

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Statistical analysis

In this research, a one-way analysis of variance (ANOVA) test was used to check the homogeneity of the descriptive information of the groups. In inferential statistics, the normality of the data distribution and the homogeneity of the variances were first examined, and the paired t-test was used to compare the scores of the subjects in each group with their eyes open and closed. All the statistical process of the research was carried out at a significance level of 0.05 with SPSS software, version 22.

Results

The results of the one-way ANOVA test to compare the demographic information of the subjects for the homogeneity of the groups in the variables of age, year, weight, and body mass index have determined that there is no significant difference between the groups in these indices (P>0.05). The results of the data normality test showed that the distribution of all measured data in the research groups was normal (P>0.05). Also, the results of Lon's test showed that the distribution variances of all measured data were equal (P>0.05). Therefore, a paired t-test was used to compare scores in two conditions with eyes open and eyes closed.

The results of the paired t-test in Table 2 have shown that there was a significant difference in the variables of ankle sways, hip sways, and the ratio of hip-to-ankle sways in both anterior and posterior disturbances in the CAI group between open and closed eyes (P<0.05).

The results of the paired t-test in Table 3 have shown that there was a significant difference in the variables of ankle sways, hip sways, and the ratio of hip-to-ankle sways in both anterior and posterior disturbances in the Coper group between open and closed eyes. (P<0.05).

Table 3. The results of the paired t-test in the open and closed eye conditions of the Coper group

Variables	Direction of Movement	Eye Condition	Mean±SD	Grade Difference (Grade)	df	P
Hip strategy	Anterior perturbation	Open eyes Closed eyes	4.08±0.56 6.96±1.07	2.50	14	0.001
	Posterior perturbation	Open eyes Closed eyes	4.98±1.70 7.46±1.26	2.48	14	0.001
Ankle strategy	Anterior perturbation	Open eyes Closed eyes	3.72±0.62 5.68±1.07	1.96	14	0.001
	Posterior perturbation	Open eyes Closed eyes	4.56±1.41 5.83±1.19	1.27	14	0.021
Hip strategy	Anterior perturbation	Open eyes Closed eyes	1.10±0.11 1.25±0.20	0.15	14	0.003
Ankle strategy	Posterior perturbation	Open eyes Closed eyes	1.08±0.23 1.30±0.22	0.22	14	0.001

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Table 4. The results of the paired t-test in the open and closed eye conditions of the prone group

Variables	Direction of Movement	Eye Condition	Mean±SD	Grade Difference (Grade)	df	P
Hip strategy	Anterior perturbation	Open eyes Closed eyes	3.32±0.37 5.5±0.86	2.18	14	0.001
	Posterior perturbation	Open eyes Closed eyes	4.86±1.09 6.46±0.63	1.6	14	0.001
Ankle strategy	Anterior perturbation	Open eyes Closed eyes	3.28±0.36 4.86±1.07	1.58	14	0.001
	Posterior perturbation	Open eyes Closed eyes	4.33±1.01 5.23±0.72	0.9	14	0.021
Hip strategy	Anterior perturbation	Open eyes Closed eyes	1.01±0.05 1.15±0.18	0.14	14	0.002
Ankle strategy	Posterior perturbation	Open eyes Closed eyes	1.11±0.10 1.28±0.19	0.17	14	0.006

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The results of the paired t-test in Table 4 have shown that there was a significant difference in the variables of ankle sways, hip swings, and the ratio of hip-to-ankle sways in both anterior and posterior disturbances in the prone group between open and closed eyes (P<0.05).

The results of the paired t-test in Table 5 have shown that there was a significant difference in the variables of ankle sways, hip sways, and the ratio of hip-to-ankle sways in both anterior and posterior disturbances in the healthy group between open and closed eyes (P<0.05).

The results of the one-way ANOVA test in Table 6 showed that there is a significant difference in anterior perturbation with open eyes between the research groups in the variables of hip joint sways (P<0.05), ankle joint sways (P<0.05), and the ratio of sways (P<0.05). Table 6 shows the differences in sways between open and closed eyes in the anterior and posterior directions and the sways of the hip joint, ankle joint, and the ratio of sways. The order of the most sways in all variables was from the group of CAI to Coper, prone to injury, and healthy. This means that as the subject goes from a healthy and uninjured state to a higher degree of injury, the difference in sways between the two states of open and closed eyes increases, which indicates a weaker balance.

Discussion

The present study aimed to investigate the effect of eliminating visual feedback on balance recovery strategies in a variety of ankle injuries and healthy individuals. The findings of the research showed that by removing visual feedback in all groups (CAI, Coper, prone to ankle injury, and healthy), the amount of ankle sways, hip sways, and the ratio of hip to ankle sways in both anterior and posterior disturbance was more than the state of open eyes and these changes were significant in each group (P<0.05). In various studies, the importance of visual information on balance maintenance and balance recovery strategy has been examined, and the results of the present study are in line with previous studies [37-39]. The information obtained through this source (vision) constitutes the main part of the sensory feedback

Table 5. The results of the paired t-test in the open and closed eye conditions of the healthy group

Variables	Direction of Movement	Eye Condition	Mean±SD	Grade Difference (Grade)	df	P
Hip strategy	Anterior perturbation	Open eyes Closed eyes	0.92±0.29 2.06±0.84	1.14	14	0.001
	Posterior perturbation	Open eyes Closed eyes	1.38±0.67 2.60±0.66	122	14	0.001
Ankle strategy	Anterior perturbation	Open eyes Closed eyes	1.69±0.55 2.36±0.93	0.67	14	0.005
	Posterior perturbation	Open eyes Closed eyes	2±0.70 2.92±1.08	0.92	14	0.021
Hip strategy	Anterior perturbation	Open eyes Closed eyes	0.77±0.19 0.87±0.13	0.1	14	0.001
Ankle strategy	Posterior perturbation	Open eyes Closed eyes	0.89±0.24 0.99±0.39	0.1	14	0.001

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Table 6. The results of the one-way ANOVA test to compare the difference between open and closed eyes in groups

Variables	Direction of Movement	CAI	Coper	Prone to AI	Healthy	F	P
Hip strategy	Anterior	2.68	2.50	2.18	1.14	257.085	0.001
	Posterior	2.48	2.48	1.6	1.22	65.457	0.001
Ankle strategy	Anterior	2	1.96	1.58	0.67	53.166	0.001
	Posterior	1.4	1.27	1.27	0.92	58.882	0.001
Hip strategy	Anterior	0.24	0.15	0.14	0.1	59.077	0.001
Ankle strategy	Posterior	0.26	0.22	0.17	0.1	23.868	0.001

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when performing sports skills and plays an important role in performing most of the skills [40]. It should be said that the vision system, the vestibular system, and the body's sensory system provide important information to maintain balance, and the reduction or elimination of vision as a disorder in the most central sensory source leads to significant negative effects on the balance recovery strategy [41]. Probably due to the reduction of information transmission from the body position to the central nervous system, postural fluctuations increased, and corrective commands were carried out with short accuracy, and finally, hip and ankle sways occurred more in the condition of eliminating visual feedback. The results obtained from the present research state that closing the eyes (removing visual feedback) in the state of causing a posterior and anterior disturbance in the groups of CAI, Coper, injury-prone, and healthy groups can significantly increase the hip and ankle sways. Jilk et al. (2014) stated that closing the eyes has an effect on the amount of hip and ankle sways of the subjects [42] and the changes indicated larger movements of the center of gravity in the range of the support surface. Liu et al. (2007) reported that in a static state with closed eyes, the amount of sways in the center of gravity increases from 22 to 56% and these sways increase in response to disturbances [43]. These past studies in this field have stated that control posture is controlled through closed-loop sensory contributions relying on receiving sensory feedback from the environment, and if there is a disturbance in the input of this information, it can hurt the ability to control people's posture [44, 45]. It seems that the increase in the fluctuations of the hip and ankle joints of athletes with ankle injuries and healthy people will ultimately hamper them from restoring the balance that is created in the closed-eyes position. As a result, increasing the movements of the center of gravity in the range of the support surface decreases the ability to control the posture in dealing with disturbances applied to the body. Other findings of the present study showed a difference in the scores obtained in the ratio of the hip to ankle sways (anterior disturbance) between two open and closed eyes, in the groups of CAI (0.24), Coper (0.15), prone (0.14), and healthy (0.1). Also, this difference in posterior disturbance ratio was in CAI (0.26), Coper (0.22), prone (0.17), and healthy (0.1) groups. This shows that the order of the most sways in all variables from the group of CAI to Coper, prone to injury, and healthy, which indicates the greater effectiveness of balance recovery strategies due to the removal of visual feedback in the group of CAI. From another point of view, these results indicate the greater dependence of these people on the visual system in case of disturbances in the proprioceptive systems.

The findings obtained in this study showed that the research groups applied different mechanisms and responses to restore balance after stimulating in the anterior and posterior directions. The main reason for this can be related to the history of injury of the athletes in the Coper and CAI. The CAI group showed more sways than the other groups due to poor balance. The severity and history of injury can be considered a risk factor for balance strategy recovery disorder in people who face external disturbances. Also, the healthy group used their ankle joints more to maintain and restore body balance after causing a disturbance and sudden speed, while prone subjects, Coper, and CAI used their hip joints more. According to the results obtained from previous studies, joints close to the support surface are the main factor in maintaining balance. Based on this, it can be concluded that healthy people can overcome external postural disturbance and maintain their balance by using joints that are close to the support surface. However increasing sways in Coper and CAI have led to increased use of the hip joint strategy, this action can be a suitable transition to maintain and restore balance in the absence of visual feedback. The results of this section are in line with the study of Karbalaeimahdi et al. (2020) who stated that patients with CAI have balance deficits, especially in the internal-external direction, compared to Coper and healthy people, which can be due to damage to the external ligaments ankle and some proprioceptive receptors located in the external ligaments of the ankle [23]. Probably, the changes in the ankle muscle responses in people with CAI can affect the balance recovery strategies and transfer it from the ankle to the hip [46]. Transferring balance recovery strategies to the hip can play an important role in reducing the ability of athletes to control their posture and subsequently increasing their risk of re-injury [47]. Among other possible reasons for choosing the hip strategy in the group of CAI and Coper, we can mention the decrease in muscle strength in the injured ankle, which becomes weak as a result of CAI [48]. However, to confirm this role of muscles, similar research is needed to evaluate the electrical activity of the distal and proximal ankle muscles during the evaluation of balance recovery strategies.

In this regard, it has been reported that the weakness of the muscles around the ankle can lead to a decrease in the appropriate torque in the ankle (to restore balance). In this way, before the body sways are controlled using the ankle torque, the center of gravity is far away from the support surface and forces the person to use the hip strategy as the dominant strategy to restore balance [49]. It also seems that closing the eyes, which causes the loss of an important part of the information received from the environment, leads to a delay in the compensatory reaction (reaction time) in the muscles around the ankle joint and before the injured people can using the ankle strategy to control the sways, the center of gravity deviated to a further distance and the subjects had to rely more on the hip strategy to restore balance. Therefore, in addition to visual feedback, the damage caused by athletes was another important factor in this research, which influenced the sways of the joints of the lower limbs. Neuromuscular dysfunction occurs following an ankle sprain and manifests as proprioceptive and proprioceptive sensation, as well as peroneal and tibial nerve damage. Disturbance in restoring balance, change during leg movement, and non-uniformity of muscle function have been proven as consequences of ankle injury [50]. In this study, it was found that the injury-prone and Coper subjects had similar performance in regaining balance in their open and closed eyes condition. However, the performance of these two groups in restoring balance has been reported to be better than the CAI group and weaker than that of athletes.

The results of this research can provide useful information for coaches and athletes in designing exercises. In athletes with CAI, there is more weakness of postural control, and this factor has caused these people to use the hip strategy to restore balance. It seems that designing exercises to improve balance, increase proprioceptive, and increase muscle strength can strengthen the proximal and distal muscles of the ankle joint so that athletes do not use countermeasure reactions of the hip joint to maintain balance. For people who are prone to ankle injuries and Coper, it is suggested that coaches consider neuro-muscular control exercises during training for the athletes to maintain the ankle strategy during functional activities of these athletes. Also, considering the role of balance recovery strategies in functional activities, it is recommended that the trainers screen the balance recovery strategies at certain time intervals. If coaches see the transfer of these strategies from the ankle joint to the hip joint, they can provide corrective solutions. Therefore, special attention should be paid to balance recovery strategies and factors affecting it in athletes with ankle injuries to control posture in training plans for ankle sprain rehabilitation. It is also suggested to use proprioceptive exercises and visual feedback to increase reliance on other balance control systems in maintaining balance and balance recovery strategies in athletes.

According to the important findings of this study, however, there were some limitations in the process of implementing this study. The biggest limitation of this study is that it coincided with the spread of COVID-19. So, the people at that time faced social restrictions and the researchers could not use a larger statistical sample size and female gender in their research. Another limitation of this research was the closure of university and laboratory spaces, which made it difficult for researchers to access more variables. One of the limitations of this research was the lack of examination of issues related to daily activities, mental state, sleep, diet, and lifestyle of people. Probably, removing these limitations for the implementation of the research could provide other useful information to the researchers and the athlete's community. However, the implementation of this research had its strengths and weaknesses. The use of the athlete's community, the use of people prone to ankle injury, and Cooper for a more accurate comparison, the use of valid and reliable tools, and the design of the research method based on the needs of the research are the strengths of this research. The researchers hope that the findings of this study will be used by the community of athletes and coaches. Also, the single gender of the subjects, and the lack of use of other laboratory variables such as range of motion, proprioception, and muscle strength among these groups are other weak points of the research. Also, in the end, future researchers are suggested to compare the factors of muscle activity, proprioception, and range of motion of the distal and proximal ankle joints in athletes with CAI, Cooper, and those prone to injury.

Conclusion

To summarize the research findings, it should be said that the current research showed that the reduction or elimination of vision as a disorder in the most central sensory source leads to significant negative effects on the balance recovery strategy of athletes, especially those with CAI. Also, in addition to visual feedback, ankle injuries can play an important role in transferring balance recovery strategies from the ankle to the hip and provide the basis for reducing the balance ability in athletes. Therefore, special attention should be paid to balance recovery strategies and factors affecting it in athletes with ankle injuries to control posture in training plans for ankle sprain rehabilitation.

Ethical Considerations

Compliance with ethical guidelines

This research was approved by the Ethics Committee of the Sports Sciences Research Institute (Code: IR.SSRC.REC.1398.090). The subjects had no obligation to continue their cooperation. At the same time, the principle of confidentiality was respected for all information of individuals.

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Authors' contributions

All authors equally contribute to preparing all parts of the research.

Conflict of interest

The authors declared no conflict of interest.

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