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RESEARCH ARTICLE

THE EFFECTS OF VISION ON STAIR DESCENT: KINETIC AND KINEMATIC ANALYSIS

Ata Elvan[1], Metin Selmani[2], Mehmet Alphan Çakıroğlu[2], Salih Angın[3], İbrahim Engin Şimşek[1]

[1] Dokuz Eylül University, School of Physical Therapy and Rehabilitation, İzmir, Türkiye
[2] Dokuz Eylül University, Institute of Health Sciences, İzmir, Türkiye
[3] Cyprus International University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Nicosia, TRNC

ORCID: A.E. 0000-0002-6478-433X; M.S. 0000-0002-0519-8584; M.A.Ç. 0000-0003-2710-788X, S.A. 0000-0003-1623-2845, İ.E.Ş. 0000-0001-8784-6604

Corresponding author: Ata Elvan, **E-mail:** ata.elvan@deu.edu.tr
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ABSTRACT

Purpose: The purpose of this study was to examine the effects of vision on stair descent activity.
Material and Methods: Twenty healthy participants aged between 20-22 (21 years) were included in the study. The patients were asked to walk on a platform with a height of 15 cm from the ground and a length of 4 meters, get down on a 30*60 cm long force platform at the end of the platform and continue walking. Test was repeated with glasses that reduced the light by 90%. Kinetic data were obtained with the Kistler Force platform. The data collected from the first contact of the person's foot to the force platform until the contact of the same foot with the platform was recorded. Descriptive statistics are given as median. Wilcoxon signed-rank test with Bonferroni correction was used to compare within-group measurement values.
Results: There were significant differences in the Min region on X-axis, the second peak on the second axis, and the second peak on Y-axis ($p<0.025$). When the kinematic parameters were compared, it was found that there was a significant difference between the min peaks of the ankle, hip, and knee joints ($p<0.025$).
Conclusion: If the vision is disrupted, even the person tries to minimize the injury risk caused by the uncontrolled movement, he/she is not able to take control of the midstance and push-off phase of the related lower extremity. It is necessary to also assess the kinetic and kinematic parameters of the contralateral lower extremity in order to broadly analyze the stair descent activity.

Keywords: Stair Descent, Vision, Kinetic, Kinematic

INTRODUCTION

During activities of daily living, the human body interacts with many internal and external forces most of which are repetitive in nature. Such forces include but not limited to forces of muscles during different phases of gait, joint reaction forces, ground reaction forces and pertubation forces from other individuals. One example is gait, as several forces act on different parts of the body depending on the phase of the gait cycle (1, 2). Muscles, articular cartilage, menisci, and ligaments, the contractile and non-contractile structures of the body, absorb some of the internal and external forces during gait. During the process of force absorption, the aforementioned contractile and non-contractile structures form a movement-specific stiffness. Proper movement-specific stiffness can

Figure 1. Instrumented staircase was used in this study. Height of wooden platform from ground = 0,15 m, length = 4 m. Force platform length = 0,6 m, width = 0,4 m.

only be achieved by the interaction of musculoskeletal and central nervous systems (3, 4). It is obvious that the stiffness coefficient of the muscular system may be altered by the neuromuscular mechanisms during the movement (5). Neuromuscular mechanisms (such as short-latency stretch reflex) function to prevent injuries in addition to providing a smooth movement. Short latency reflexes are generated just before the dissipation of the shockwave that is caused by the force in action (6). Thus, the muscle responses to shockwaves are generated (7). Through proprioceptive feedback, the body makes preparations for movements via anticipatory reactions. The data obtained by the golgi tendon organ, Pacinian capsules, and Ruffini corpuscles generate information about the position of the lower extremity. If there are any problems or alterations in this integration the reaction may not be performed correctly, and injuries may occur (8).

There are numerous studies that cover many aspects of stair ascent and descent in the literature (9-12). There are studies about kinetic and kinematic parameters of stair ascent and descent related to not only the different age groups but also the different types of stairs (9, 13, 14). According to Schick et al. and Speechley&Tinetti, stair activities, which pose no threats to adults, take an important part of the fall injuries (15, 16). There may be deviations from the normal movement pattern in stair descent related to the physiological alterations due to aging (17, 18). As a result of a prolonged double limb support phase, increased amount of support, and decreased movement velocity a safer pattern is chosen. These adaptations may be indicated as a result of muscle strength loss, moreover, in marathon runners, the more difficult stair descent activity may be performed backward after fatigue. But as it was reported in the previous studies, the stair descent activity may be negatively affected by muscle strength loss, cardiovascular disorders, poor vision, proprioception loss, and balance problems (19). First and foremost, the integration of vision, balance, and protective reactions is of utmost importance. It is known that with poor or disrupted vision, the balance and anticipatory reactions are also disrupted. Vision helps to maintain balance by working with the somatosensory system and vestibular system and also works as a crucial and reliable data source. Postural control problems may occur during the activities of daily living, with impaired vision or in a short moment of absence of mind (20-22). The proof in literature is scarce during stair descent activity, the disruption of the information, which is provided by the vision. The aim of this study was to investigate the possible alterations in kinetic and kinematic parameters related to stair descent activity with impaired vision.

Table 1. Demographic characteristics of participants

	Participants (n:20) Median – (IQR)
Age *(years)*	21 – (19.00 – 24.50)
Gender	12 male – 8 female
Body Height *(cm)*	167.5 - (164.25 – 176.50)
Body Weight *(kg)*	67.00 - (53.50 – 77.00)
BMI *(kg/m^2)*	22.18 – (20.07 – 24.65)

IQR: Interquartile Ratio

MATERIAL AND METHODS

The study was conducted between May 2016 and August 2016 at the Dokuz Eylul University School of Physical Therapy and Rehabilitation. Ethics committee approval was obtained from the Dokuz Eylul University Non-Interventional Ethics Committee Commission (Date: 30.07.2015, Decision Number: 2015 / 18-30). Inclusion criteria; 1 – Able to stand or walk without pain, 2- Being between the ages of 18-35. Exclusion criteria was having any history of orthopedic surgery.

The participants wore no clothes other than minimalistic undergarments, which enabled precise

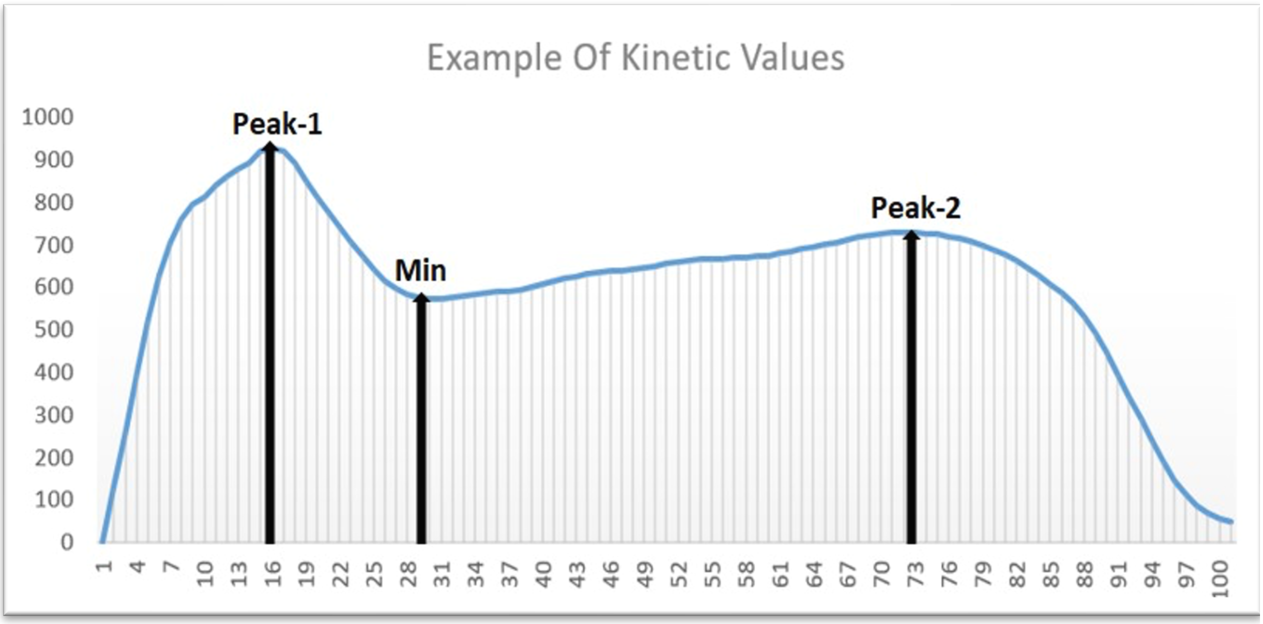

Figure 2. Example of Kinetic Values

marker placement and were barefoot during the evaluations. Demographics of the participants were recorded before starting the study protocol. After recording demographics, to conduct motion analysis; 1- ankle diameter measurement, 2-knee joint diameter, 3- pelvic diameter, 4- pelvic height, 5- lower extremity length measurements were performed respectively. The participants were asked to walk at a comfortable speed they prefered on a previously prepared wooden platform and to descend on the 30 * 60 cm long platform (force plate) at the end of the platform (Figure 1). The height of the wooden platform is 15 cm and its length is 4 meters. Before the assessment, participants were asked to repeat the activity at least 5 times as trials. After completion of trials, participants were asked to perform the same activity 2 more times; 1 without goggles and 1 with goggles, which reduces incoming light rays by 90%. Starting position on the wooden platform was selected so that the participants were able to complete the activity regardless of their step length. In both cases (with and without goggles), kinetic and kinematic data were obtained. Kinematic data were obtained by BTS™ motion analysis system with marker placement according to Helen Hayes protocol and kinetic data were obtained by the Kistler™ platform.

Reference kinetic values were determined for the data to be taken just before the assessment with the motion analysis (Figure 2). From the moment the person's foot first contacted the force platform, the data was collected until the same foot was removed from the platform. The collected data was transformed into a 100-frame sequence. After the sequence separation, the force platform data were analyzed in three sections according to the graph below (Figure 2). The first highest data obtained from the force platform (Peak-1), the lowest data following this data (Min) and, the next highest data (Peak-2) have been examined in three sections (Figure 2). Related to this data, lower extremity joints' range of motion, which were converted into 100-frame sequences, were selected for their corresponding degrees for statistical analysis.

Statistical analysis was performed using Statistical Package for Social Sciences 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) program. Descriptive analyzes were presented as mean±standard deviation. The Wilcoxon Signed-Rank test was used to compare the kinetic and kinematic data obtained according to both test conditions. Bonferroni correction was used ($p < 0.025$).

RESULTS

Demographic characteristics of the participants are given in Table 1. The study included 20 participants (12 male, 8 female).

The times of the participants' completion of the step-stroke activity and the kinetic and kinematic

Table 2. Kinetic and kinematic parameters during stair descent

	Eyes Open Tests Mean (SD)	**Eyes Closed Tests** Mean (SD)	***p***
X-P1 (N/m)	-85,0669 (48,82)	-33,5844 (120,34)	0.102
X-Min (N/m)	19,0055 (24,43)	-22,5217 (76,90)	**0.011***
X-P2 (N/m)	97,4075 (59,84)	42,6134 (65,02)	**0.020***
Y-P1 (N/m)	1148,6610 (269,21)	1363,9350 (448,43)	0.031
Y-Min (N/m)	516,2985 (125,73)	649,4260 (284,20)	0.064
Y-P2 (N/m)	684,7400 (195,34)	840,1770 (327,46	**0.024***
Z-P1 (N/m)	-14,2709 (61,25)	-4,6049 (56,29)	0.647
Z-Min (N/m)	-7,1203 (33,23)	-6,4119 (54,52	0.968
Z-P2 (N/m)	-8,9046 (48,04)	-12,2751 (62,27)	0.968
Ankle-P1 (deg)	0-,3440 (13,64)	-,9357 (16,02)	0.601
Ankle-Min (deg)	-1,3898 (12,23)	-4,4987 (11,50)	0.550
Ankle-P2 (deg)	5,0800 (9,39)	-6,0859 (12,70)	**0.007***
Knee-P1 (deg)	4,1356 (5,23)	8,3401 (13,98)	0.433
Knee-Min (deg)	3,7895 (5,06)	13,2903 (16,27)	**0.021***
Knee-P2 (deg)	3,7006 (3,23)	14,6074 (17,40)	0.030
Hip-P1 (deg)	8,1122 (7,52)	8,4012 (9,56)	0.970
Hip-Min (deg)	0,5163 (9,53)	6,2215 (7,83)	**0.007***
Hip-P2 (deg)	0,1042 (12,33)	3,6931 (10,85)	0.204

(*=p<0.025) Wilcoxon Signed Rank Test, p values were corrected with Bonferroni correction. X-P1: Kinetic 1st peak of X-axis, X-Min: Minimum Kinetic of X-Axis, X-P2: 2nd peak of X-Axis. Ankle-P1: 1st peak degree of ankle joint movement in the sagittal plane. (-) values refer to dorsiflexion of the ankle, hyperextension of the knee, and extension of the hip joint. (+) values refer to plantarflexion of the ankle, flexion of the knee, and flexion of the hip joint.

parameters shown during this activity are shown in Table 2 in both conditions with the eyes open and eyes closed.

As shown in Table 2, there were significant differences in the Min region on X-axis, the second peak on the second axis, and the second peak on Y-axis ($p<0.025$). When the kinematic parameters were compared, it was found that there was a significant difference between the min peaks of the ankle, hip, and knee joints ($p<0.025$).

DISCUSSION

The purpose of this study was to investigate the alterations in kinetic and kinematic parameters during stair descent activity with disrupted vision. Kinetic parameters were examined related to the foot initially contacted the force platform whereas kinematic parameters were examined related to the foot and lower extremity. There was not any study on this topic in the literature to our knowledge. In our study, with the disruption of vision, we found that the ground reaction force was increased and, the excessive energy (load), normally absorbed by related muscles and joints, could not be absorbed thus, the force required for push-off could not be generated.

In the literature, there are studies in which kinetic and kinematic analyzes are performed during stair ascent and descent activity (9, 12, 23). There are also publications on the importance of vision during stair descent (23, 24). In a study by Buckley et al., kinetic parameters during blurred vision were examined. According to the results of the study, participants tried to take a safe step until the somatosensory sense of the foot, which initially contacts the ground, perceived. It was determined that the participants tried to descend the steps cautiously (23). In our study, the sense of vision was blocked and it was tried to prevent them from developing a safe strategy. Therefore, the results of our study are different from the results of Buckley et al.'s study. However, similarly, it was found in our study that body control was tried to be achieved during step descent by providing ground contact. In the study of Hamel et al., the relationship between decreased vision during stair descent activity and falling was tried to be defined with parameters related to the foot's contact with the ground (24). The results of the study showed that vision is important when the foot is in contact with the ground. In the study of Brinker et al., it was found that the markers set to support the sense of vision have beneficial effects (25).

The results of stair descent activity with minimal vision are somewhat similar to the results of functional drop landing activity. During drop landing activity, the body follows the specific pattern and, the related structures of the body try to absorb the shockwave. During undisrupted vision, when initial contact is performed with the forefoot, lower extremity joints move within a greater range of motion to reduce the velocity of the body. The greater range of motion enables eccentric control of the muscles and absorption of the shockwave. It is known that if the range of motion is not between optimal range, injuries may occur. It was indicated that a greater hip and knee joint range of motion may prevent ACL injuries (26). The human body reacts to increased ankle dorsiflexion range or velocity of the body by increasing the hip and knee joint range of motion (26). We also found similar results in our study. Participants completed the activity with an increased average flexion range of motion during minimal vision from initial contact to push-off phase including the midstance phase. The shockwave caused by the ongoing uncontrolled activity was tried to be eliminated by the flexion posture just before initial contact and in the y axis, the person was able to absorb shockwave as soon as initial contact occurs. In addition to flexion posture throughout the movement, the significant difference in flexion posture in the knee and hip joints was seen at the "min" area, in which the shockwave is trying to be absorbed. However, during the remaining part of the movement –push-off phase-, ankle dorsiflexion continued to increase. Thus, the ankle joint was not able to generate the required force for the push-off phase. The data of decreased kinetic parameters at the "x" axis confirms this hypothesis.

As the kinetic data were examined it was identified that the data significantly deviated from the normal values. The deviation was only not significant at the "z" axis. This effect indicates that the medial-lateral stability of the lower extremity presents similar results under both conditions. As the data of the "y" axis were examined, it was indicated that the aforementioned greater flexion posture was effective in neutralizing shockwaves during initial contact and absorption phases. The force influencing the "y" axis was detected to be increased during movement however, a significant effect was seen in the P2 area. Increased "y" axis force indicates the contralateral extremity was not able to transfer body weight under control. But during the increase in P2 area, it was indicated that the lower extremity was still trying to eliminate the shockwave and not able to generate the moment for propulsion.

Our study has two limitations. The former is that we only examined the kinematic parameters of the lower extremity in the sagittal plane, not axial rotation. Thus, it is not known that the alterations may or may not influence the results. The latter is that we were not able to analyze the contralateral lower extremity due to the limitations of our motion analysis system. We were not able to gather kinetic and kinematic parameters related to the contralateral lower extremity.

CONCLUSION

During the stair descent activity, vision is one of the most important parameters for the correct postural control. If the vision is disrupted, even a healthy individual tries to minimize the injury risk caused by the uncontrolled movement, he/she is not able to take control of the midstance and push-off phase of the related lower extremity. We believe further studies should also include the assessment of the kinetic and kinematic parameters of the contralateral lower extremity to broadly analyze the stair descent activity.

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REFERENCES

1. Dufek JS, Bates BT. The evaluation and prediction of impact forces during landings. Medicine and Science in Sports and Exercise. 1990;22(3):370-7.

2. Santello M. Review of motor control mechanisms underlying impact absorption from falls. Gait & posture. 2005;21(1):85-94.
3. DeGoede K, Ashton-Miller J, Schultz A. Fall-related upper body injuries in the older adult: a review of the biomechanical issues. Journal of biomechanics. 2003;36(7):1043-53.
4. Dugan SA, Bhat KP. Biomechanics and analysis of running gait. Physical Medicine and Rehabilitation Clinics. 2005;16(3):603-21.
5. Zajac FE. Muscle and tendon: properties, models, scaling, and application to biomechanics and motor control. Critical reviews in biomedical engineering. 1989;17(4):359-411.
6. Duncan AD, McDonagh MJ. Stretch reflex distinguished from pre-programmed muscle activations following landing impacts in man. The Journal of physiology. 2000;526(2):457-68.
7. Dyhre-Poulsen P, Simonsen EB, Voigt M. Dynamic control of muscle stiffness and H reflex modulation during hopping and jumping in man. The Journal of physiology. 1991;437(1):287-304.
8. Teh J, Firth M, Sharma A, Wilson A, Reznek R, Chan O. Jumpers and fallers: a comparison of the distribution of skeletal injury. Clinical radiology. 2003;58(6):482-6.
9. Riener R, Rabuffetti M, Frigo C. Stair ascent and descent at different inclinations. Gait & posture. 2002;15(1):32-44.
10. Cohen HH. A field study of stair descent. Ergonomics in Design. 2000;8(2):11-5.
11. Cluff T, Robertson DGE. Kinetic analysis of stair descent: Part 1. Forwards step-over-step descent. Gait & posture. 2011;33(3):423-8.
12. Beaulieu FG, Pelland L, Robertson DGE. Kinetic analysis of forwards and backwards stair descent. Gait & posture. 2008;27(4):564-71.
13. Livingston LA, Stevenson JM, Olney SJ. Stairclimbing kinematics on stairs of differing dimensions. Archives of physical medicine and rehabilitation. 1991;72(6):398-402.
14. Protopapadaki A, Drechsler WI, Cramp MC, Coutts FJ, Scott OM. Hip, knee, ankle kinematics and kinetics during stair ascent and descent in healthy young individuals. Clinical biomechanics. 2007;22(2):203-10.
15. Schick S, Heinrich D, Graw M, Aranda R, Ferrari U, Peldschus S. Fatal falls in the elderly and the presence of proximal femur fractures. International journal of legal medicine. 2018;132(6):1699-712.
16. Speechley M, Tinetti M. Falls and injuries in frail and vigorous community elderly persons. Journal of the American Geriatrics Society. 1991;39(1):46-52.
17. Buckley JG, Cooper G, Maganaris CN, Reeves ND. Is stair descent in the elderly associated with periods of high centre of mass downward accelerations? Experimental gerontology. 2013;48(2):283-9.
18. Cavanagh PR, Mulfinger LM, Owens DA. How do the elderly negotiate stairs? Muscle & Nerve Supplement. 1997;5:S52-5.
19. Startzell JK, Owens DA, Mulfinger LM, Cavanagh PR. Stair negotiation in older people: a review. Journal of the American Geriatrics Society. 2000;48(5):567-80.
20. Redfern MS, Yardley L, Bronstein AM. Visual influences on balance. J Anxiety Disord. 2001;15(1-2):81-94.
21. Lestienne F, Soechting J, Berthoz A. Postural readjustments induced by linear motion of visual scenes. Exp Brain Res. 1977;28(3-4):363-384.
22. van Asten WN, Gielen CC, van der Gon JJ. Postural movements induced by rotations of visual scenes. J Opt Soc Am A. 1988;5(10):1781-1789.
23. Buckley JG, MacLellan MJ, Tucker MW, Scally AJ, Bennett SJ. Visual guidance of landing behaviour when stepping down to a new level. Experimental brain research. 2008;184(2):223-32.
24. Hamel KA, Okita N, Higginson JS, Cavanagh PR. Foot clearance during stair descent: effects of age and illumination. Gait & Posture. 2005;21(2):135-40.
25. den Brinker BPLM, Burgman LJ, Hogervorst SMJ, Reehorst SE, Kromhout S, van der Windt J. The effect of high-contrast marking of treads on the descent of stairways by low-vision people. International Congress Series. 2005;1282:502-6.
26. Fong C-M, Blackburn JT, Norcross MF, McGrath M, Padua DA. Ankle-dorsiflexion range of motion and landing biomechanics. J Athl Train. 2011;46(1):5-10.