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Effect of Carrying Two Types of Packs in Two Heights of Placement (Lumbar and Thoracic) on some Kinematics Variables of Primary Schoolboys

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Original Article

Abstract

Introduction: The present study is conducted with the aim to investigating the effect of carrying backpacks and modified packs (with three bags that distribute the load equally in front and back of trunk) in two heights of placement including lumbar and thoracic, on craniovertebral angle, trunk angle, and the angle of hip and knee joints among the 8-11-year-old schoolboys during walking.

Materials and Methods: Considering the inclusion and exclusion criteria, 27 schoolboys participated in the study and fulfilled five tasks including walking without a pack, carrying backpack on lumbar area, backpack on thoracic area, modified packs on lumbar area, and modified packs on thoracic area. Then, the photogrammetry of the right side was performed by a camera (Panasonic, Japan). The target angles were measured as single-blind with Kinovea motion analysis software. Repeated measure analysis of variance (ANOVA) was used to compare tasks.

Results: The results showed significant decrease in craniovertebral angle (increased forward head posture) in the task of carrying backpacks on thoracic area in contrast with the lumbar area, as well as increase in trunk forward lean while carrying packs ($P < 0.05$) that was significantly higher in the backpack carrying tasks ($P < 0.05$). But in craniovertebral angle, significant difference was not seen while carrying modified packs in contrast with the control group ($P > 0.05$).

Conclusion: Carrying packs on lumbar area caused less postural variations, thus seeming better. Changing the position of the load concentrated on the back can more affect the kinematic parameters of schoolboys. The modified pack carriage only caused a little trunk forward lean which was lesser than that of backpack carriage, so it can be a good alternative for students' backpack.

Keywords: Backpack; Schoolchildren; Kinematics; Pack position; Gait

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Introduction

It is important to study the carrying of different backpacks from clinical, physiological, and biomechanical perspectives (1). Researchers have linked carrying loads in different shapes and weights to discomfort, fatigue, and some musculoskeletal pain and injuries such as back pain (2), as well as postural abnormalities and movement defects (3). Carrying loads by children is mostly performed with backpacks (6-4). The average relative weight of the backpack of elementary schoolboys in Iran is reported to be 11.31 ± 4.13 percent of body weight, which is carried for about 21 minutes (7). Various studies recommend carrying a backpack with a load of less than 10% (8) or 15% (2) of body weight for children. Of course, these results are limited to short distances on a flat surface (9). Examination of posture when carrying a backpack is one of the most important determining criteria (1). Some investigations have focused on the different shapes of the backpack (10) and its height of placement on the back (11). However, given their scarcity and contradictory results, especially in kinematic indicators, further research in this area is still needed. Therefore, in the present study, the effect of changing the height of position of two types of backpacks on kinematic indicators is investigated.

The load position on the back may affect the energy consumption and mechanics of the body (12). It is generally believed that it is better to place the load or backpack on the upper area of the back (13); while

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research has reported different results. Reviewing biomechanical and physiological studies, Knapik et al. suggested that placing the load at the bottom or middle of the back may be better for walking on uneven ground, but placing the load at the top of the back may be suitable for walking on flat ground (12). Golriz and Walker, in a review of articles on backpacks up to 2010, found research on their placement height insufficient (5). About their shapes, the double-compartment design (14-17) and to some extent the front backpack (18) were better than the backpacks. From the available sources, only a few studies have examined the kinematic parameters affected by the height of placement of the backpack, which have shown contradictory results (13,16,19-22). In general, the results of biomechanical studies on the height of the backpack on the back in children are contradictory; some researchers have not reported a difference (1,19,23), but some find it more appropriate to be in the lower back (13,20-22, 24) or in the middle or upper torso (16,25). The reasons for these discrepancies can be attributed to the different methods of measurement, the backpack weight, how the load height is displaced, and the age difference of the participants.

Further investigations are required to address the effect of load-bearing on gait performance in children (4). Abdullah et al., after reviewing articles on trunk kinematics in students, concluded that further studies were needed to identify the appropriate load limit and its position in children (26). Although carrying a backpack is common among students, less research has been accomplished on them compared to adults (26-28). Given the studies, the suitable load for the students' backpacks 10% of their body weight (26), and in general, it is recommended to distribute the load around the trunk, rather than its concentration on the back (29). Therefore, the present study aims to investigate the effect of carrying a backpack and a modified three-compartment backpack, at two heights of lower (lumbar region) and middle (thoracic region) of the back, on the craniovertebral, trunk, and thigh and knee angles of 8 to 11-year-old boys.

Materials and Methods

This study was a quasi-experimental study with repeated measures and single-blind (evaluator) design conducted to explore the effect of carrying two types of backpacks weighing 10% of the body weight at two heights of lumbar and thoracic areas on the kinematic variables. The study was approved with the code of ethics IR.UT.SPORT.REC.1397.002 and the Iranian Registry of Clinical Trials (IRCT) code IRCT20180607039995N1. Blinding of the participants was not possible; because they were wearing the backpacks, but they were not aware of the research hypothesis during the performance (21). The statistical population of the study consisted of 8 to 11-year-old healthy schoolboys in Tehran, Iran. Using the repeated measures design with five measurements and an effect size of 0.25 and a power of 0.90, the G*Power software version 2.9.1.3 suggested 26 subjects (19). 28 people were invited to participate in the study using the convenience sampling method and by applying the inclusion and exclusion criteria. With the removal of one person due to cancellation and incomplete assignments, the data of 27 people were analyzed.

The study inclusion criteria included the age range of 8 to 11 years, male gender, the individual's and parents' consent, and the right hand and right foot dominance. Having musculoskeletal disorders (MSDs) (30), spinal cord and lower extremity injuries in the three months leading up to the measurements (19), gait abnormalities and obvious posture based on the New York test (30), drug use (19), history of surgery (31) ear infection (31), having a fever in the 72 hours leading up to the measurements (19,31), and drinking tea and coffee (caffeine) in the three hours before the measurements (19) were also considered as the exclusion criteria. All measurements were taken after school and at 10 to 13 o'clock.

A camera (NV-GS75, Panasonic, Japan) related to the gait analyzer (belt-driven instrumented HP Cosmos Gaitway treadmill with Kistler force plates, Germany) was used. The camera was embedded on the graduated stand of the device and perpendicular to the sagittal plane at a distance of 5 meters from the centerline of the treadmill at a height commensurate with the participants' thighs, and filming was performed from the right at a frequency of 50 frames per second. Other measurement tools included a form for data collection and basic data recording, a standard backpack (Diteyn Team), a modified three-compartment backpack [including back, front-right, and front-left in the form of a wearable vest based on the Ramadan and Al-Shayea study design (10) made by the researcher], and a tape measure for measuring height.

By conducting a pilot study on three participants, the method of measurements with related instruments was reviewed and debugged. The measurement site was the Motion Control Laboratory, School of Electrical Engineering, University of Tehran. Before and while conducting the study, calls were made to recruit volunteers in schools, educational classes, and even residential complexes. Screening was performed to select eligible individuals and then the measurement process was described in detail to the volunteers and they were assured that their information would remain confidential. Attending the laboratory, the informed consent form was signed by the participant's parent. The measurement process was performed at specific stations. Other measurements included weight (using the device force plate) and height [using the tape measure next to the wall according to the International Society for the Advancement of Kinanthropometry (ISAK) method] performed by the researcher, in addition, the main stage of the measurement was fully supervised by him.

Five steps of the measurement (one without backpack and two types of backpacks in both lumbar and thoracic positions) were performed in one day. To avoid the effect of fatigue, the tasks were performed randomly for each subject and the participant rested between wearing two backpacks. Walking speed was determined and recorded self-selectively at the stage of familiarity with the treadmill with 5 minutes of walking. This speed specific to each subject was fixed in all of his other tasks. For each task, the subject walked for 2 minutes and his video was recorded. To adjust the weight of the backpacks as 10% of the body weight, the students' daily items including books, bottles, writing instruments, and other objects were used in a balanced way on the frontal and sagittal plates in the two types of backpacks. The necessary load for the backpacks was prepared with the help of a colleague. In the modified backpack, the weight of the backpack in the back compartment and two front compartments was adjusted half-and-half.

The position of the load was considered as the lower or lumbar position by adjusting the lower line of the backpack at the level of the fifth lumbar vertebra and as the middle or thoracic position by adjusting the lower line of the backpack at the twelfth dorsal vertebra (22). In the present study, the whole backpack was lifted as much as possible by manipulating its straps. Then, to precisely adjust the backpack load line in the above-mentioned positions, by placing a piece of foam in the bottom of the backpack, it was adjusted to the appropriate level. The foam placement was required for the thoracic condition in eight smaller subjects. Physical markers including "tragus, middle of the acromion process, spinous process of the seventh cervical vertebra (protruding marker), greater trochanter of the femur, lateral femoral condyle, and lateral malleolus" were identified by touch and marked with a 1 cm luminous label. The subjects were tested with skinny sports shorts and T-shirts or only with sports shorts. Considering the effect of dual task activities (along with cognitive function) on performance while carrying the load (4), the subjects were asked to look at the opposite wall. Their focus was considered to be normal.

After transferring the videos to the Kinovea software (Kinovea Version 0.8.27, Joan Charmant and contributors, 2018), the last 20 seconds of each task were separated. Then three gait cycles were randomly specified from each. The angles of the hip and knee joints, the cranio-vertebral angle, and the trunk angle were obtained in three stages of heel impact, midstance (proximity of both feet), and toe-off in each cycle in the Kinovea software, then the mean of the three cycles was calculated. The markers of the lateral femoral condyle, greater trochanter of the femur, and lateral malleolus were used for the knee angle, the vertical line and the line of the greater trochanter to the lateral femoral condyle for the thigh angle, the vertical line and the line of the greater trochanter to the seventh cervical vertebra for the trunk angle (20,32), and the horizontal line and the line of the seventh cervical vertebra to the tragus for the craniovertebral angle. In order for single-blinding, all these calculations were performed in the Kinovea software by a sports biomechanics expert and the data were imported into Excel. All of these angles were compared for each of the three stages of the gait with their corresponding stages in the backpack-free (control) task. For the trunk and head index, the mean values of the three stages were also calculated for each task.

Descriptive statistics and Shapiro-Wilk test were employed for the demographic characteristics of the participants and to detect the normal distribution of data, respectively. The data were analyzed using repeated measures analysis of variance (ANOVA) and least significant difference (LSD) in SPSS software (version 23, IBM Corporation, Armonk, NY, USA).

Results

27 students with a mean age of 9.70 ± 1.29 years, a mean height of 141.46 ± 8.04 cm, a mean weight of 35.79 ± 12.50 kg, and a mean body mass index (BMI) of 17.51 ± 4.25 kg/m^2 participated in the present study. Normal distribution of data for each variable of each participant was confirmed using the Shapiro-Wilk test ($P > 0.05$). Other assumptions of the repeated measures ANOVA test, including the homogeneity of variances and the compound symmetry of the covariance matrix, were considered. According to the data in table 1, carrying a backpack in the thoracic region, only in the craniovertebral angle, compared to the lumbar position, led to a significant decrease in values (increase head forward lean) ($P < 0.001$).

Table 1. Main study variables and results of the least significant difference (LSD) post hoc statistical test

Positions Variable		Without a backpack	Backpack, lumbar	Backpack, thoracic	Modified backpack, lumbar	Modified backpack, thoracic	P
Craniovertebral angle (degree)	Heel impact	42.61 ± 5.23	41.04 ± 4.91 0.019*	38.64 ± 3.48 < 0.001*	43.61 ± 5.72	42.50 ±6.01	0.001Ɨ 0.001‡ < 0.001#
	Mid-stance	40.83 ± 5.00	39.95 ± 4.44	37.57 ± 3.55 < 0.001*	41.95 ± 5.79	41.22 ± 5.77	0.001Ɨ 0.032‡ < 0.001#
	Toe-off	42.35 ± 5.32	40.78 ± 4.45 0.017*	39.29 ± 4.52 0.001*	42.92 ± 5.85	42.31 ±6.12	0.043Ɨ 0.002‡ 0.001#
	Mean	41.93 ± 5.12	40.59 ± 4.46 0.016*	38.50 ± 3.72 < 0.001*	42.83 ± 4.74	42.01 ± 5.90	0.004‡ < 0.001#
Trunk angle (degree)	Heel impact	3.33 ±2.48	-1.31 ± 3.20 < 0.001*	-0.95 ±2.76 < 0.001*	0.50 ±3.21 < 0.001*	0.87 ±2.82 < 0.001*	< 0.001‡ 0.002#
	Mid-stance	2.59 ±2.66	-1.27 ± 3.00 < 0.001*	1.09 ±2.10 < 0.001*	0.35 ± 2.58 < 0.001*	1.00 ± 2.90 0.009*	0.002‡ < 0.001#
	Toe-off	1.47 ± 2.82	-2.13 ± 2.70 < 0.001*	-2.45 ± 2.63 < 0.001*	-0.75 ± 2.53 < 0.001*	-0.45 ± 2.98 0.002*	< 0.001‡ < 0.001#
	Mean	2.46 ± 2.40	-1.57 ± 2.85 < 0.001*	-1.50 ±2.13 < 0.001*	0.03 ± 2.54 < 0.001*	0.47 ± 2.66 < 0.001*	< 0.001‡ < 0.001#
Hip angle (degree)	Heel impact	19.26 ± 3.42	20.29 ±2.94	19.22 ± 3.87	20.34 ± 3.89	20.24 ± 2.95	
	Mid-stance	-0.54 ±3.38	-0.88 ± 3.09	-1.10 ± 3.53	-0.38 ±3.39	-0.61 ± 3.02	
	Toe-off	-10.30 ±4.65	-10.78 ± 5.07	-11.23 ± 4.34	-10.75 ± 4.48	-10.86 ± 5.14	
knee angle (degree)	Heel impact	177.69 ± 2.00	176.43 ± 3.27 0.020*	177.52 ± 2.25	177.0 ± 2.93	177.22 ±2.71	
	Mid-stance	169.80 ± 4.11	170.13 ± 5.60	170.56 ± 5.21	169.73 ± 5.00	169.75 ± 5.42	
	Toe-off	142.23 ±7.16	143.25 ±7.57	143.61 ± 7.36	143.86 ± 6.26	143.44 ± 8.18	

For all angles, the position of the limb in the clockwise and counterclockwise direction was considered negative and positive, respectively.
*significant without a backpack (control). †significant difference between lumbar and thoracic backpack positions, ‡significant difference between common backpack and modified backpack in lumbar position, #significant difference between common backpack and modified backpack in thoracic position

No reduction of the craniovertebral angle was observed in carrying the modified backpack (P = 0.140). Bending the trunk forward with carrying the backpacks showed a significant increase (P < 0.001) which was significantly higher in the normal backpacks compared to the modified ones. There was no significant difference in hip angle in any of the tasks (P > 0.050). The knee joint angle was significantly reduced compared to the control only in the heel impact stage by carrying the backpack in the lower back (P = 0.020).

Discussion

Students are at their development age and have not fully developed in terms of motor control (33). Therefore, it is very important to study the stresses imposed to them. It is generally believed that carrying a backpack in the higher back is easier (21,34). However, studies have suggested that the center of mass of the load is close to the center of gravity of the body (35). In the present study, the effect of carrying a common backpack and a modified backpack weighing 10% of body weight in both lumbar and thoracic positions on children's kinematic parameters was investigated. It should be noted that little research has been carried out in this area. The hypothesis was that the values of the variables would change more in the thoracic position, especially for the common backpack. In other words, carrying a backpack in the lumbar position is probably better than in the thoracic position.

Carrying a backpack in both positions resulted in a significant increase in head forward lean compared to walking without a backpack. The rate of head-forward lean increase in thoracic backpacking was significantly higher than that of the lumbar backpacking, but no significant difference was observed in the modified backpacking tasks. Therefore, carrying a backpack in the lumbar region (with loose straps) was less likely to cause the head to move forward, but carrying a modified three-compartment backpack not only did not change the position of the head compared to without the backpack, but also created no difference in the two heights of placement. Carrying both backpacks with a weight of 10% of the body weight in both positions, led to a significant increase in trunk forward lean compared to walking without backpacks. The trunk angle while carrying the modified backpack was significantly less than carrying the common backpack.

Changing the height of the backpacks did not cause a significant change in the trunk angle. In the hip and knee joints, only the knee angle at the heel impact stage with carrying the backpack in the lower back was reduced by 1.26 degrees compared to the control group. This reduction in heel impact alone cannot lead to a strong conclusion about the effect of independent variables. In general, changing the height of position of the backpack alone changed the position of the head; so that the placement of the backpack in the thoracic region increased the head forward lean relative to the lumbar position. Therefore, the change in the height of the backpack changed the movement control strategy in carrying it, but this change did not occur for the modified backpack. As a result, the hypothesis regarding the craniovertebral angle was confirmed.

The choice of middle (thoracic) and lower back (lumbar) positions was according to two common and possible situations for students to carry a backpack, as well as based on previous studies. Other situations where the backpack load is too high (around the shoulders) or too low (on the hips) are not common. In previous studies, the loose and tight strap terms were used to describe the position of the backpack (34). Determining the location of the backpack in some studies has been with the upper limit of the backpack (31) or with its center of gravity (11). In the present study, the lower limit of the backpack was used; Because the load of the backpack is concentrated on its bottom, and its identification and selection is easy for families and students.

Based on the acquired knowledge, several studies have investigated the effect of changing the height of the backpack and load on the kinematic and postural parameters of different parts of the body such as head and trunk and joint angles, including the studies by Bloom and Woodhull-Mcneal (36), Johnson et al. (29), Chen and Mu (11), Devroey et al. (13), Brackley et al. (20), Frank et al. (37), Abdelraouf et al. (34), Singh and Koh (1), Mackie and Legg (23) and Grimmer et al. (21). In the field of spinal arches, the studies by Brackley et al. (20) and Chow et al. (16) can also be mentioned.

Taking into account the indicators in each study, the consistent and inconsistent results are slightly different from their overall outcome. Bloom and Woodhull-Mcneal concluded that wearing a backpack the main volume of which was at the lower back led to more trunk angle. Participants, both male and female adults, wore a special backpack called rucksack in the static position. Therefore, it may not be generalizable to children carrying backpacks (36). Additionally, Johnson et al. reported more trunk and hip angles by carrying a 36-kg military backpack in a lower-to-higher back position (29). However, Grimmer et al. reported total body displacement and forward angle by wearing a backpack with a maximum weight of 10% of body weight centered at the top (T7), middle (T12), and bottom (L3). The trunk angle in the lower position (on the hip) was significantly less than the other two positions. Their evaluations were performed only in static position (21). The middle position in the study of Grimmer et al. (21) was consistent with the lumbar position in the present study. Although Frank et al. generally recommended carrying a backpack in terms of reaction force at the lumbar and shoulder joints in the lower back, no kinematic change was observed in the trunk (37). With the change in the height of the backpacks in the present study, there was no change in the trunk angle, but there was more angle in carrying the common backpack than in the modified backpack. Children may respond differently to changes in the height of the backpack when walking compared to the static position.

In the study by Singh and Koh, despite more trunk angle in the backpack weights of 10 and 15% of the body weight when placed on top of the T8 and T9 vertebrae, in the 20% weight with the backpack placed on top, the trunk angle was slightly (one degree) lower than in the lower position. They attributed these changes to the complexity and variability of the nervous system response to carrying backpacks, which requires further investigation (1). In the present study, with carrying the backpacks at a weight of 10%, no change was observed in the trunk position, which was inconsistent with the results of the study by Singh and Koh at a weight of 10% (1). In addition to the discrepancies in the results of the Singh and Koh study, the amount of the load carried in it was very high and without moving the backpack, only the load inside it was moved by placing foam (1). In their study, Brackley et al. reported the lack of change in the trunk position of children by changing the height of placement of the backpack with a weight of 15% of body weight and increasing the head forward by carrying it in the upper and middle positions relative to the lower position (20); which was similar to the present study. They also observed the least change in lumbar lordosis in the lower position (20). The proximity of the center of gravity of the load to the spine and the center of gravity of the body led to the lower changes in the lumbar direction (38) and prevented the head forward (39). In these studies (38,39), the horizontal distance of the load from the center of the body was not mentioned. It can be concluded that changing the height of the 10% load has little effect on the trunk angle, and it is the backpack load itself that causes a lot of trunk lean; the change that was greatly reduced with the modified backpack, but according to previous studies, heavier loads on the upper back or below the center of gravity of the body lead to more trunk angle (29).

In the study of Frank et al., carrying a backpack in the T7 position increased the head forward, but did not change the whole body (37), which was somewhat consistent with the findings of the present study. However, in their study, children wore backpacks only in a static state in position C7 as the upper position and in position T7 as the lower position (37). In the study by Abdelraouf et al., participants showed more head forward (reduced craniocerebral angle) when carrying a backpack with loose and long straps (in the lower back position) (34), which contradicted the results of the present study. They suggested that the backpack straps be tight and close to the top of the back, citing more stretching of the loose straps on the shoulders and upper torso (34) as the reason for this finding. The possible reasons for inconsistent results were that their participants were young and the craniovertebral angle was measured in a static position before and after 15 minutes of carrying a backpack weighing 15% of the body weight (34).

The results of a study by Devroey et al. did not also support the general idea that it is better to carry a backpack on the upper back (thoracic region). Nevertheless, placing the backpack in the lumbar region caused more trunk angle (13). Wang (40) and Singh and Koh (1) also reported that load placement on the lower back while carrying frontpacks and backpacks was generally better. Recently, a study by Chen and Mu found that placing the backpack in the lower back so that its center of gravity was at the T12 level (corresponding to the lower position in the present study, which was the lower limit of the backpack at the L5 level) was the best in terms of kinematic, electromyographic, and perception of discomfort indices. Other positions in their study were the center of gravity of the backpack in the upper back and very low (lower back) positions (11). Based on postural control information, Ou also reported that load placement in the lumbar region and carrying a frontpack were more appropriate than carrying a backpack in the thoracic region (33).

In the present study, despite half a degree lower trunk angle in the thoracic position of the backpack, the craniovertebral angle showed a significant decrease. This may be due to the tightness of the backpacks and the greater stretch on them (41), which can lead to children walking more smoothly and, conversely, increasing their head forward. Perhaps by placing the center of mass higher, despite the contraction of the abdominal muscles, the trunk enters a new compensatory posture in response to the external load on the upper back (42), but to compensate and keep the total center of mass at the support surface, the head has further inclined forward.

In the present study, by carrying backpacks with a weight of 10% of body weight, there was not much change in the thigh and knee angles in the stages of heel impact, mid-distance, and toe-off, and only a slight decrease was observed in knee angle in the heel impact. Researchers have reported changes in hip and knee angles to absorb impact and maintain dynamic balance, which are more likely to occur when carrying loads of more than 20% of body weight (43). In the study by Johnson et al., the soldiers' knee angle changed from that of the control group by carrying a 36 kg backpack only in the lower back (29). Measurement method, age, and type of task were reported as other reasons for different results (43).

Limitations

The results of the present study were limited to two-dimensional recording of the movements during short-term carriage of backpacks on a flat surface, only at a weight of 10% by school boys. Besides, no muscle activity was recorded.

Recommendations

More clear information can be obtained by removing the limitations and simultaneously recording the three-dimensional muscular and kinematic activity of the body. A modified backpack with a weight distribution on the front and back of the body can be a good alternative to a student backpack. Therefore, it is suggested to be considered by industrial designers and ergonomics experts.

Conclusion

The results of the present study indicated that the backpack placement in the lower back (lumbar region) is better in terms of head-forward position, but no difference was observed in the indicators of trunk position and hip and knee angles. Moreover, the modified backpack only caused a slight trunk bend, which was much less compared to the common backpack. Therefore, it supports the idea of distributing load around the trunk, and the modified backpack can be a good alternative to students' backpacks. The displacement of the common backpack position compared to the modified backpack caused more changes in the variables. Hence, the displacement of the load focused on the back can be more influential on students' kinematic parameters. However, the results are limited to instantaneous changes with 10% weights at the smooth surface.

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Authors' Contribution

Ali Akbar Jadidian: ideation and selection of study subject, background study and study design and framework, financing of the study, preparation of study supplies and equipment, calling and inviting participants, study implementation and data collection, preliminary calculations and final data extraction, data statistical analysis and interpretation, summarizing the results of relevant studies and preparing the initial manuscript, preparing and approving the manuscript for the journal, correspondence: Mohammad Hosein Alizadeh: support and approval of the idea and design and scientific and executive management of the study, support in providing equipment and laboratory, specialized supervision over the implementation and method of data collection, interpretation of results and evaluation and integration and scientific approval of the manuscript, evaluation and final approval of the manuscript for the publication, specialized commenting in responding to referees' comments; Elham Shirzad, scientific and executive support and design and management of study, support in providing equipment and laboratory, specialized supervision over the study execution and data collection, supervision of calculations and extraction of data, evaluation and scientific approval of the manuscript, evaluation and final approval for the publication, expert opinion in responding to referees' comments.

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The present study was performed in the Motion Control Laboratory, School of Electrical and Computer Engineering, University of Tehran. No comment or assistance has been provided in providing supplies, participants, data collection and analysis, and manuscript preparation.

Conflict of Interest

The authors declare that there is no conflict of interest.

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