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Original Article

Influence of motor instruction words on body movements in step-over motions

Hirokazu Kitao, RPT, MS[1)*], Noriyuki Kida, PhD[2)], Teruo Nomura, PhD[2)], Chie Fukada, PhD[2)], Takayuki Nakamoto, RPT[1)], Masaaki Otani, RPT[1)], Yoshihiko Nomura, MD, PhD[1)]

[1)] *Department of Rehabilitation, Kyoto Kizugawa Hospital: 26-1 Hirakawanishirokutan, Jyoyo-shi, Kyoto 610-0101, Japan*
[2)] *Arts and Sciences, Kyoto Institute of Technology, Japan*

Abstract. [Purpose] To quantitatively analyze the characteristics of movements evoked by certain motor instruction words on the basis of measurements of ankle elevation and related body movements in step-over motion tasks. [Participants and Methods] Sixty-one healthy adult participants were presented with motor instructions and asked to step over an obstacle in accordance with the instructions. The motor instructions were as follows: “Raise your XX (body part) up YY (expression)” in four combinations using “thigh” and “knee” for body part and “high” and “firmly” for expression. Using Kinect to analyze movements, ankle elevation, trunk-anteversion angle, hip-flexion angle, and knee-flexion angle were measured and statistically processed. [Results] With respect to body part, there was no significant difference in the mean and standard deviation (individual variation) values for ankle elevation. With respect to expression, hip joint and knee joint were bent significantly more for “high” than for “firmly”, and although the mean value for ankle elevation was high, ankle elevation standard deviation (individual variation) values were significantly lower for “firmly” than for “high”. [Conclusion] Explicit motor instruction words such as “high” may be effective in improving performance, while ambiguous motor instruction words like “firmly” may be effective in stabilizing movements.

Key words: Motor instruction, Step-over motion, Performance

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INTRODUCTION

When teaching certain motor skills, instructors often use verbal instructions to transmit motor information to the learner. In rehabilitation medicine, verbal motor instructions are used as one of the means to explain motor techniques, draw out images of movements, and otherwise change the patient’s performance. For the task of climbing a balance ladder, Feltz explains that it is useful to use linguistic cues to draw attention to task-related clues[1)]. Housner likewise reports on the effectiveness of verbal instructions in improving motor skills[2)].

Verbal motor instructions have been approached by researchers from two perspectives: internal focus of attention on the body movement itself, and external focus of attention on the environment and other factors. In a study using a ski simulator, Wulf and others found differences in motor learning that stemmed from variation in internal and external focus of attention[3, 4)].

There are a multitude of word combinations that can be used in motor instructions, however, and instruction depends in large part on the personality and experience of the instructor. Research is still lacking as to how a learner’s performance may be affected by different word combinations in verbal motor instructions, and a better understanding is essential to more efficient teaching and learning of motor skills.

*Corresponding author. Hirokazu Kitao (E-mail: hirokazu.kitao@gmail.com)

As a basic inquiry into different body movement-focused motor instruction word combinations and changes in performance, the purpose of this study is to quantitatively assess changes in body movements evoked by various motor instructions based on measures of ankle elevation and related body movements demonstrated in step-over motion tasks.

The reason for selecting step-over motion as the motion task is that the elderly are prone to stumbling and falling due to the decline in physical functions such as lower limb muscle strength and balance ability with aging[5, 6)], and the teaching of the step-over motion is a movement that is often performed in rehabilitation training from the perspective of preventing falls in the elderly[7–10)]. The step-over motion is also an appealing choice for study because of the comparative ease of biomechanical analysis and the availability of literature on the participant[11–14)].

PARTICIPANTS AND METHODS

The participants in this study were 61 healthy adults who were physical therapists and occupational therapists working at Kyoto Kizugawa Hospital and who without any neurological or orthopedic disorders (30 males, 31 females; average age: 28.8 ± 5.5 years, average height: 165 ± 9.3 cm). In line with ethical considerations pursuant to the Declaration of Helsinki, participants were fully informed in writing and orally about the purpose and methods of the study, the benefits and disadvantages of participating in the study, and the risks, and their consent to participate in the experiment was obtained.

Experiments were conducted indoors. An LCD monitor (Iiyama ProLite PLE2473HDS, 295 mm × 523 mm) was placed 3.0 m in front of the participant, who was instructed to stand. During the experiment, motor instructions were displayed on the monitor (108 Pt font size, MS Gothic) and the participant was asked to step over an obstacle in accordance with the instructions. Each instruction was displayed for five seconds before moving on to the next instruction, with a blank screen displayed in between. The obstacle was a bar set up 15 cm in front of the participant at a height of 20 cm (Fig. 1).

Step-over motions were analyzed using Kinect (Redmond, WA, USA)[15)]. Kinect is a device that estimates skeletal models using a depth sensor, and it is inexpensive and easy to install[16)]. Although it has been reported to produce errors in hip joint angle measurements for walking and knee angle for jumping and landing when compared to the highly accurate Vicon (Oxford, UK), Kinect is generally said to a certain level of reliability as a device for analyzing motor function[17–19)].

The starting position was standing at rest, and the right leg served as the leading leg for step-over motions. There were no restrictions on line of sight or swinging of the arms, and participants were told to respond only to the motor instructions that were displayed. One step-over movement constituted one trial. Motor instructions consisted of combinations of the body parts of "thigh" and "knee" and the expressions of "high" and "firmly" in four trials: "Raise your thigh up high and step over the obstacle", "Raise your knee up high and step over the obstacle", "Raise your thigh up firmly and step over the obstacle", and "Raise your knee up firmly and step over the obstacle". These motor instruction words were subject to analysis. For the selection of motion instruction words, we showed the images of the step over motion to several people except for the participants of the experiment in advance, and conducted a questionnaire survey on the body parts and expressions to change the straddling motion. We adopted "thigh" and "knee" as the body parts most frequently mentioned, and "high" and "firm" as the expressions most frequently mentioned.

In addition, to avoid learning effects that participants were given other motor instructions such as "Look carefully and step over the obstacle" and "Quickly step over the obstacle" that did not include words that were subject to analysis. In total, there were 21 trials, which comprised one set, and each participant completed five sets during the experiment. Instructions

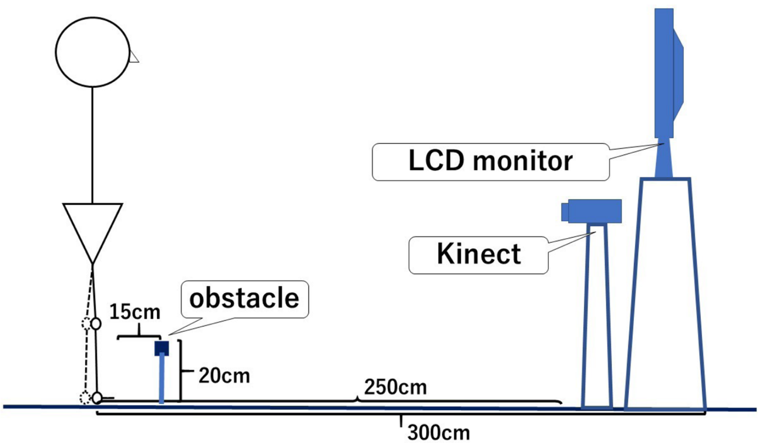

Fig. 1. Test environment.
The LCD display was placed 300 cm in front of the participant, Kinect was placed 250 cm in front of the participant, and the obstacle was a bar 20 cm high and 15 cm in front of the participant.

were presented on the monitor randomly for each set, and sufficient break were provided between sets to avoid any impact from fatigue. During the break period, the participants were instructed not to recall the trials they had performed to avoid learning effects.

We used Kinect for Windows V2 (Microsoft, Redmond, WA, USA) to collect data for analysis of motor function[20]. The Kinect device was placed 2.25 m in front of the participant at a height of 1.0 m from the floor, and kinematic data (of the 25 skeletal model joint points that can be measured with Kinect, 3D coordinates formed from the four points of right shoulder joint, hip joint, knee joint, and foot joint) were collected at 30fps and saved in CSV format. We defined the resting coordinate system as a right-handed coordinate system with the orthogonal direction from the front of the participant at the start of the trial as the X axis, the direction forward from the front of the participant as the Y axis, and the upward vertical direction as the Z axis.

As a performance variable, we calculated ankle elevation as the difference between the foot joint at maximum elevation and the position of the foot joint Z coordinate at rest. All joint angles were defined along the YZ plane. Knee flexion angle was defined as the angle formed by the vector pointing from the hip joint to the knee joint and the vector pointing from the knee joint to the foot joint, hip flexion angle was defined as the angle formed by the vector pointing from the shoulder joint to the hip joint and the vector pointing from the hip joint to the knee joint, and trunk anteversion angle was defined as the vector pointing from the hip joint to the shoulder joint and the resting coordinate system Z axis (Fig. 2). Mean and standard deviation were calculated for each of the variables of the five sets, and standard deviation was used as an index for individual variation.

To determine the impact of motor instruction words on performance and joint angle, we conducted two-factor analysis of variance using body part (thigh, knee) and expression (high, firmly) as intra- participant factors, and we tested items with significant interaction for simple main effect through multiple comparison with Bonferroni correction. Significance level was 5% and we used SPSS 23 (IBM, New York, NY, USA) for statistical analysis.

RESULTS

We conducted two-factor analysis of variance using body part (thigh, knee) and expression (high, firmly) as intra- participant factors. Results indicated no significant interaction with respect to mean for each variable. For expression, there was a significant main effect for ankle elevation, hip angle, and knee joint angle, with “high” having significantly high values compared to “firmly”. For body part, there was a significant main effect for knee joint angle, with “thigh” having significantly high values compared to “knee” (Table 1).

With respect to individual variation for each of the variables, there was no significant interaction for ankle elevation and trunk anteversion angle. There was a significant main effect for ankle elevation with respect to expression, with “high” having significantly high values compared to “firmly”. There was a significant interaction for hip flexion angle and knee flexion

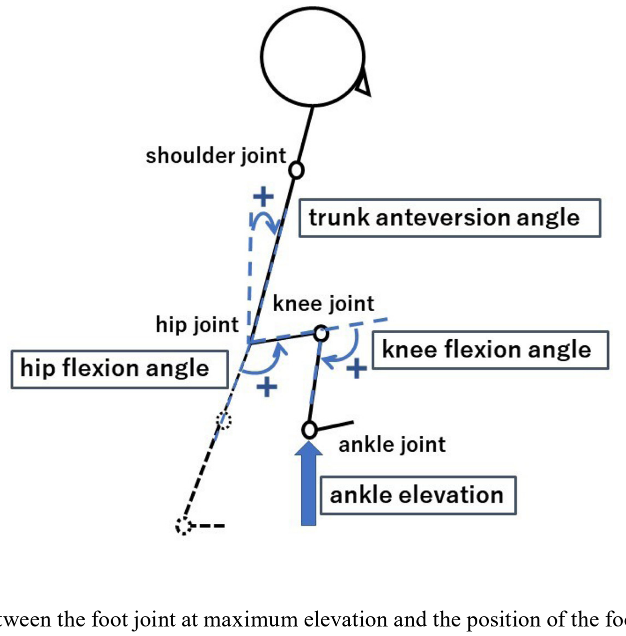

Fig. 2. Measurement items.
Ankle elevation: the difference between the foot joint at maximum elevation and the position of the foot joint Z coordinate at rest.
knee flexion angle: The angle formed by the vector pointing from the hip joint to the knee joint and the vector pointing from the knee joint to the foot joint. Hip flexion angle: The angle formed by the vector pointing from the shoulder joint to the hip joint and the vector pointing from the hip joint to the knee joint. Trunk anteversion angle: The angle formed by the vector pointing from the hip joint to the shoulder joint and the resting coordinate system Z axis.

Table 1. Mean and standard deviation (individual variation) ankle elevation, trunk anteversion angle, hip flexion angle, and knee flexion angle per trial

	Knee [A]		Thigh [B]		Main effect				Interaction		
	Firmly [a]	High [b]	Firmly [a]	High [b]	Body part		Expression		Body part × Expression		
	M ± SD	M ± SD	M ± SD	M ± SD	F	p	F	p	F	p	
Mean											
Ankle elevation (cm)	42.6 ± 7.7	44.3 ± 7.2	43.2 ± 7.6	44.7 ± 7.6	1.91	0.172	42.86	0.000**	0.53	0.470	a<b
Trunk anteversion angle	7.39 ± 2.98	7.12 ± 3.07	7.10 ± 3.06	7.28 ± 2.95	0.18	0.674	0.14	0.711	3.95	0.052	
Hip flexion angle	100.9 ± 9.3	103.7 ± 10.0	101.5 ± 9.8	104.0 ± 9.8	1.48	0.229	60.88	0.000**	0.21	0.646	a<b
Knee flexion angle	116.8 ± 8.8	118.4 ± 9.2	117.9 ± 9.2	119.2 ± 9.0	4.36	0.041*	9.08	0.004**	0.05	0.830	a<b, A<B
Standard deviation											
Ankle elevation	3.94 ± 2.23	5.03 ± 2.28	4.93 ± 2.98	5.14 ± 2.93	3.03	0.087	6.98	0.010*	2.96	0.091	a<b
Trunk anteversion angle	2.41 ± 1.70	2.46 ± 1.63	2.27 ± 1.63	2.27 ± 1.61	1.56	0.217	0.05	0.833	0.04	0.839	
Hip flexion angle	5.98 ± 2.92	7.05 ± 3.24	6.92 ± 3.49	6.36 ± 2.57	0.15	0.701	0.76	0.388	6.02	0.017*	Aa<Ab, Aa<Ba
Knee flexion angle	6.62 ± 3.25	8.44 ± 4.71	7.50 ± 4.75	7.30 ± 3.38	0.11	0.746	3.34	0.072	6.41	0.014*	Aa<Ab, Bb<Ab

*p<0.05; **p<0.01.

angle, and testing for simple main effect indicated significantly high values for “knee up high” compared to “knee up firmly” and significantly high values for “thigh up firmly” compared to “knee up firmly” with respect to hip angle. With respect to knee joint angle, there were significantly high values for “knee up high” compared to “knee up firmly” and for “knee up high” compared to “thigh up high”.

DISCUSSION

With respect to expression, mean results indicate that there was significantly more bend at the hip joint and knee joint and higher ankle elevation values for “high” compared to “firmly”, and individual variation results indicate that ankle elevation values were smaller for “firmly” compared to “high”, and that hip flexion angle and knee flexion angle were smaller for “firmly” compared to “high” when “knee” was the body part.

With respect to body part, Mean of knee flexion angle was significantly greater when “thigh” instruction than “knee” instruction. The reason for this may be the difference between “knee” which is the site of the joint, and “thigh” which is the site of the bone. In the case of “knee” instruction, the focus is on the knee, and the knee joint is fixed and the lower limb is raised, whereas in the case of “thigh” instruction, the focus is not on raising the knee, and excessive fixation of the knee joint does not occur. As a result, the “thigh” instruction resulted in a slight but significant difference in knee flexion angle compared to the “knee” instruction.

Differences in word comprehension may provide one possible explanation for differences in mean and individual variation for ankle elevation depending on expression. “High” is a more explicit instruction than “firmly” and is likely to tie into higher ankle elevation when the movement is based on the objective standard of height. As discussed by Sawada et al.[21)], in reference to figurative motor instructions for children’s dance, and Fujino et al.[22)], in reference to onomatopoeia-based motor instructions for athletes, figurative motor instructions can be beneficial because they can easily convey complex meanings and images that are difficult to express, and because it is easier for learners to imagine the instructor’s intent, but at the same time, they can be ambiguous and imprecise in meaning or intent; in this experiment, since “firmly” is more abstract than “high”, it is possible that participants found it more difficult to form a concrete picture of bending at the hip joint and knee joint that would cause the leg to lift.

With respect to individual variation, however, there was less variation for ankle elevation for “firmly” compared to “high”, suggesting that the instruction made the movement highly reproducible. This supports the findings of Sawada and Fujino that figurative motor instructions make movements easier to imagine[21, 22)].

Insofar as the step-over leg-lifting motion in this experiment and our comparison of “high” and “firmly”, we found that “high” is an explicit expression that enabled the participant to lift/not lift based on quantitative self-assessment using the objective standard of height, and that it is therefore an effective instruction word for improvement of performance. This suggests that the use of the word “high” in the training of step over for the purpose of fall prevention is effective when it is used for those who have insufficient leg-lifting motion when step over.

This is not to say that ambiguous expressions like “firmly” necessarily have a negative influence on the transmission of information; since the standard for movement is self-established, there is less individual variation compared to objective expressions like “high” that may consequently benefit stability of movement and flexible transmission of information. This suggests that the use of the word “firmly” in the training of step over for the purpose of fall prevention is effective when it is used for the purpose of establishing a stable motion for those who have a certain degree of stability in the step over motion. However inquiry is necessary to determine whether similar results would be produced in the case of “far” for throwing, “fast” for kicking, or “strong” for gripping when compared to using “firmly”.

Although this study suggests that different motor instruction words, that is, the adjectives “high” as an objective expression and “firmly” as a figurative expression, result in different body movements for step-over motions, These results will help us to consider what kind of language is preferable when training straddling movements to prevent falls in rehabilitation medicine. However, although there was a significant difference in ankle-raising height between “high” and “firmly” in this experiment, it should be noted that the difference in ankle-raising height was only about 2 cm. Therefore, it is important to note that performance is not significantly affected by differences in movement instruction words alone. In actual rehabilitation training, movements are taught orally rather than visually. The impact of these different sorts of instruction words will need to be studied in further detail.

Conflict of interest

There are no conflicts of interest to disclose.

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