Visual Perception of Biomechanical Characteristics of Walking, Jumping, and Landing

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Visual perception of biological systems is one important aspect which has been considered by researchers in understanding human motion. The term «biological motion» was used by Johansson (1971, 1973) to distinguish human movement patterns from the motion of rigid inanimate objects previously utilized in visual motion perception. The emphasis, however, has been on the need for distinguishing three types of motion to describe perceived kinematic relations: the relative motion of elements to each other in the configuration, the common motion of the whole configuration relative to the observer, and the absolute motion of each element in dynamic display [Cutting and Proffitt (1982)]. Based on data collected using a video-recorder, reflective tape and high powered light for producing point-light displays, Cutting and Proffitt (1982) concluded that relative motion is automatically minimized by the visual system. Moreover, Johansson (1971, 1973) showed that all movement pattern of walking and running can be visually identified by observers without seeing the total picture. Using a similar technique, observers were able to visually recognize gender and friends by their walking patterns (Cutting and Kozlowzki, 1977; Cutting, 1978), ones' own identity (Beardsworth and Buckner, 1981), the weight of lifted objects (Runeson and Frykholm, 1983), and to the extent that evaluation of technical skill execution was sucessfully judged (Scully, 1986).

Based on the principle that relative motion is automatically minimized by the visual system, Johansson (1973), concluded that previous learning of motion patterns do not determine the perception of walking. An important factor, however, is a highly mechanical, automatic type of visual data treatment. In addition, Runeson and Frykholm (1981) stated that the dynamic variable of the event (weight of the box), is well specified in the kinematic pattern and hence the visual system is efficient in picking up such information.

Identifying cues by visual information may not be sufficient, however, to distinguish discrete skills (ie., jumping and landing) and/or continuous skills (ie., walking), especially, if the direction of the movement is reversed and if the total picture is seen as an absolute motion which includes the relative and common motion (Cutting and Proffitt, 1982). Therefore, this study was conducted to test the hypotheses that experience and familiarity are important factors in visual perception of kinematic patterns and that kinetics cannot be determined effectively by observation of kinematics. The purpose of this study is to determine: (1) the ability to visually perceive differences between a continuous skill (walking forward vs. backwards): (2) a discrete skill (jumping vs. landing); (3) the actual kinetic differences in the movement; and (4) whether individuals can distinguish between movement patterns, despite the kinetic differences, while the true pattern is reversed.

METHODS

A person was filmed in the sagittal plane walking forward and backward. The walking was recorded on the treadmill at four selected speeds: slow, medium, fast walking, and a condition which could be classified as jogging. The same person was then filmed jumping upwards and landing. The film speed was set at 24 frames/sec (coinciding with the playback mode of the projector). A Locam high speed camera was used for filming the patterns. The film was developed and then transferred to a video-tape recorder, but the order of the speed and trial was randomly assigned. In addition, a manipulation of conditions was set in order to project four conditions of walking. Two of the conditions, forward and backward walking were transferred from the film in the temporal order of occurrence (forward and backward walking). The line segment drawing in Figure 1 represents true forward walking and Figure 2 represents true backward movement. The movie film was then videotaped in reverse order, false walking backward (see Figures 3 and 4). The one same videotaping manipulation were made for the jumping and landing films.

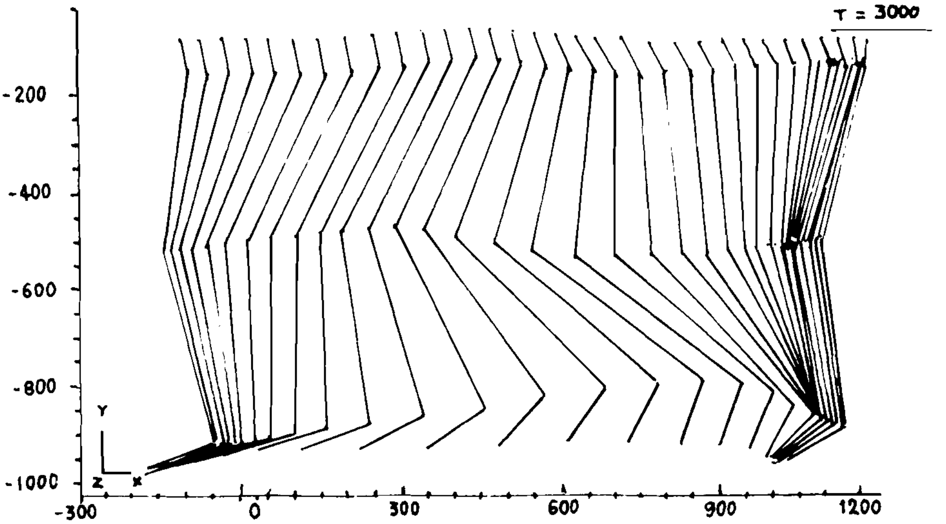

Fig. 1. True forward walking.

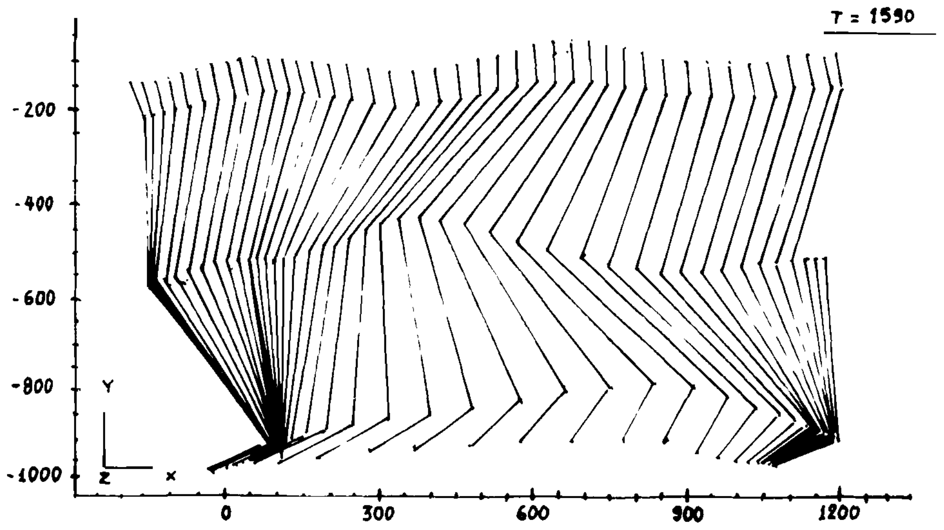

Fig. 2. True backward walking.

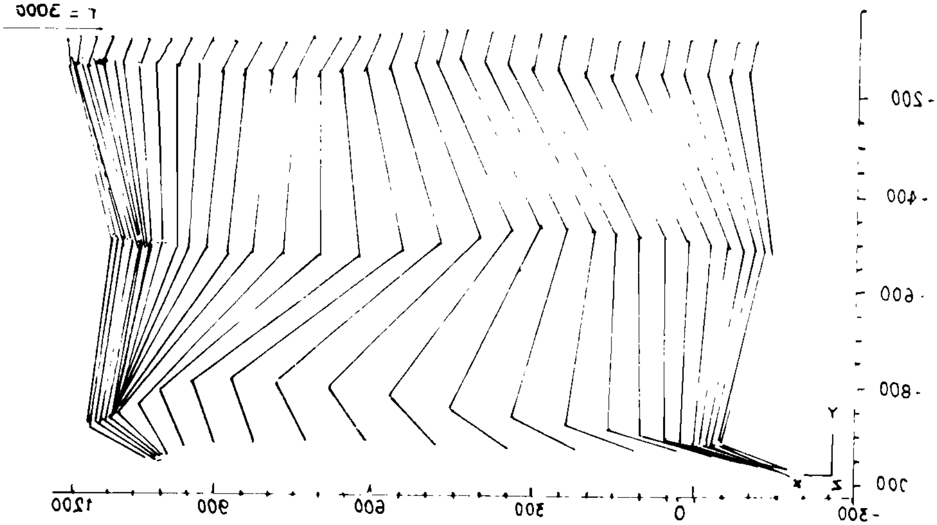

Fig. 3. False forward walking.

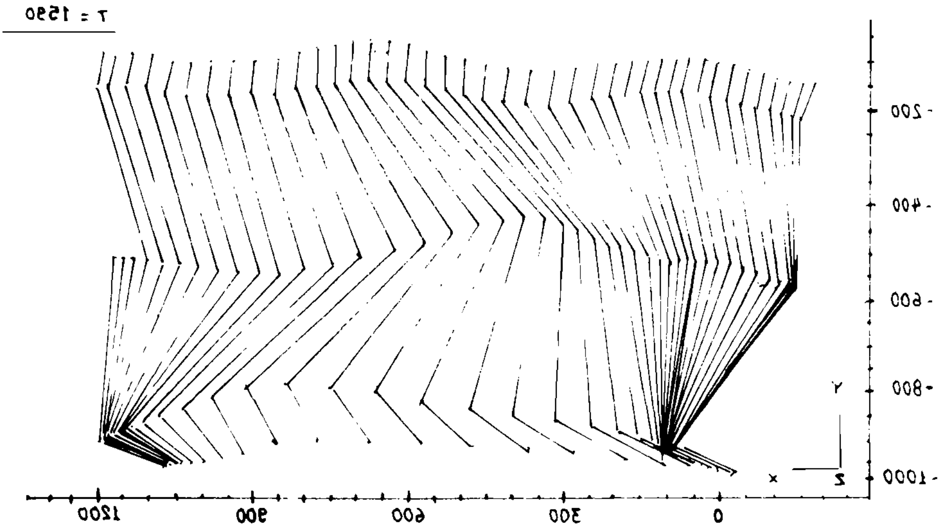

Fig. 4. False backward walking.

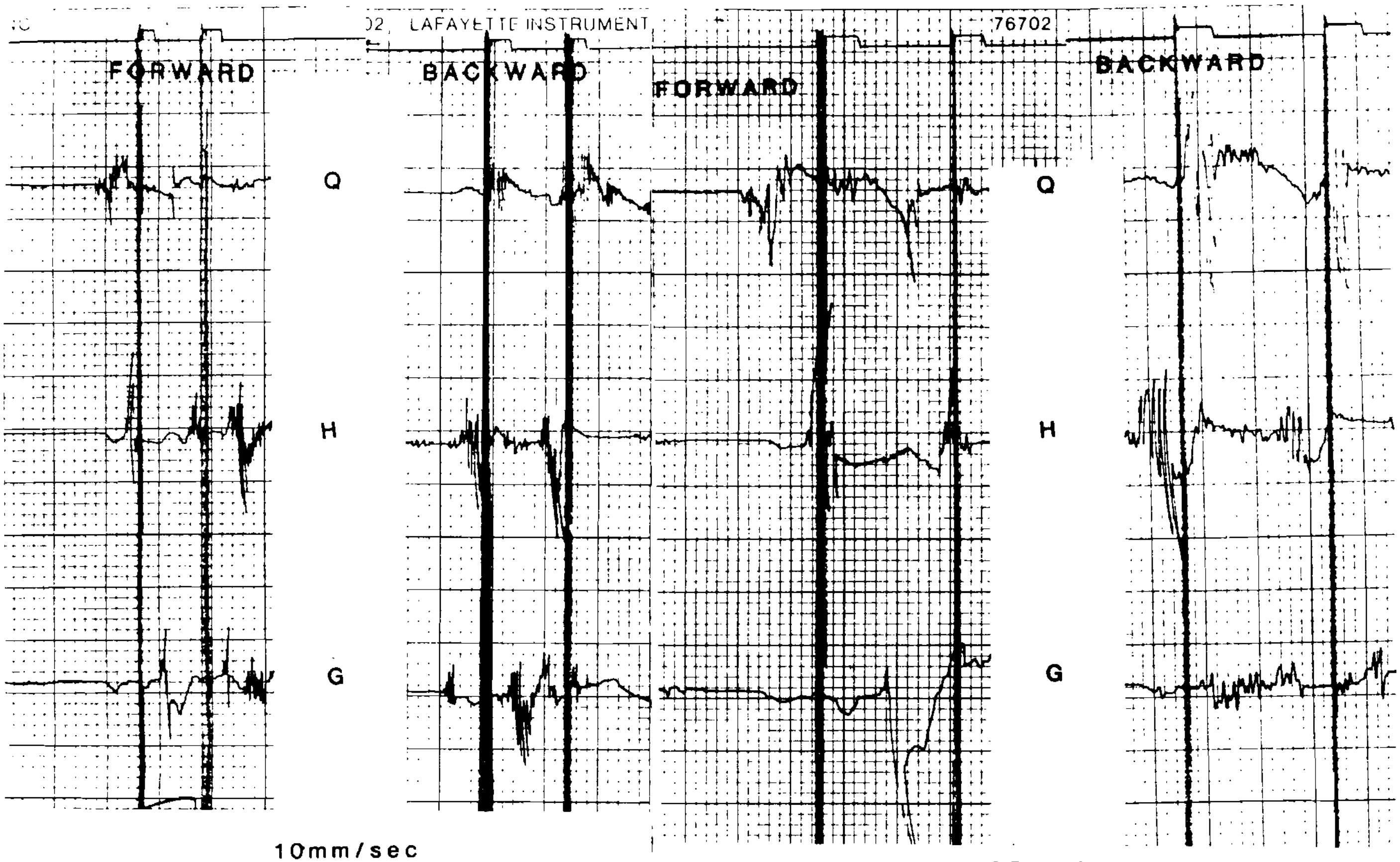

Fig. 5. EMG recording of the activity of the gastrocnemius hamstring, and quadriceps during walking forward and backward.

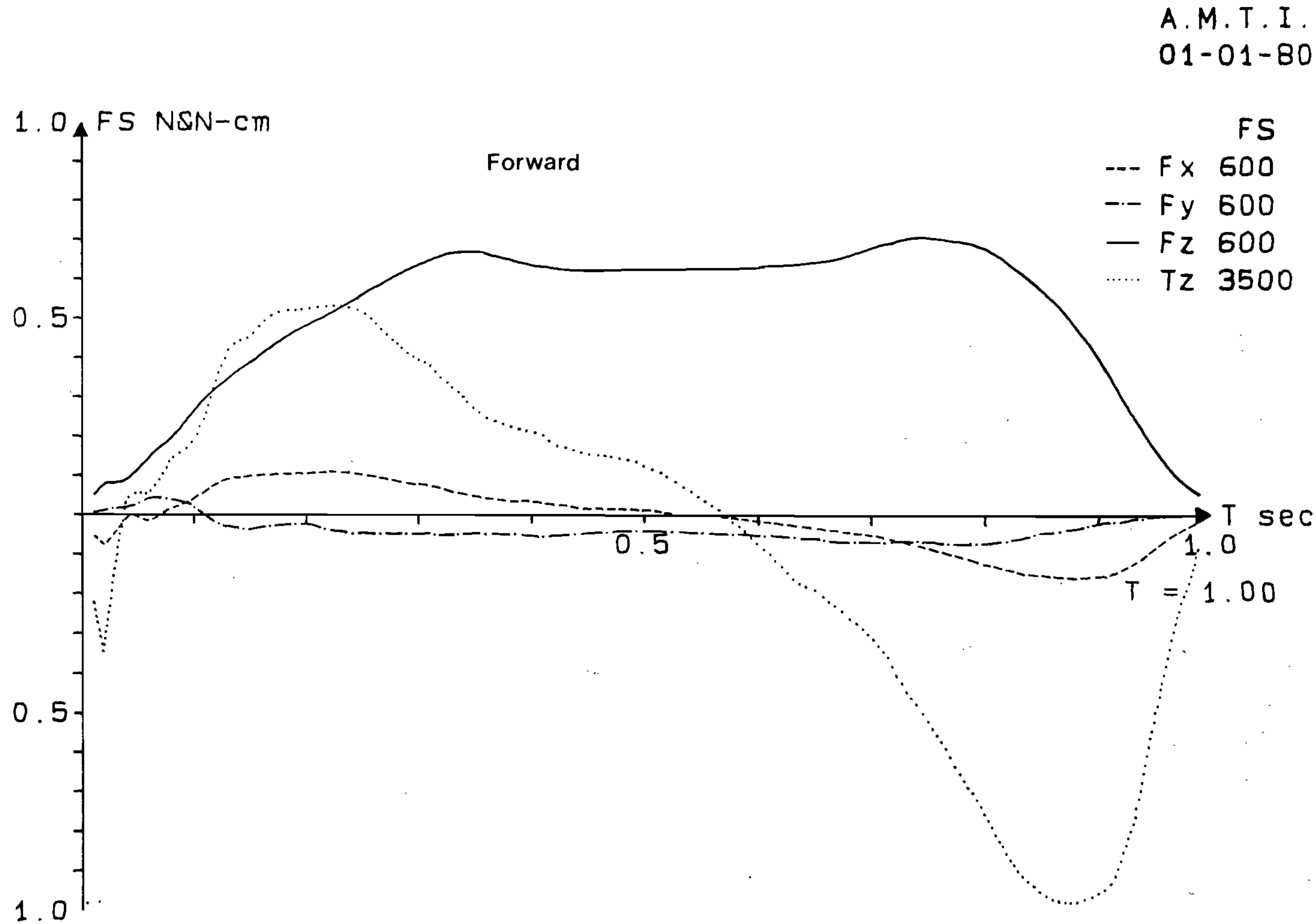
A.M.T.I.
01-01-80
1.0
FS N&N-cm
Forward
FS
Fx 600
Fy 600
Fz 600
Tz 3500
0.5
T sec
0.5
1.0
T = 1.00
0.5
1.0

Fig. 6

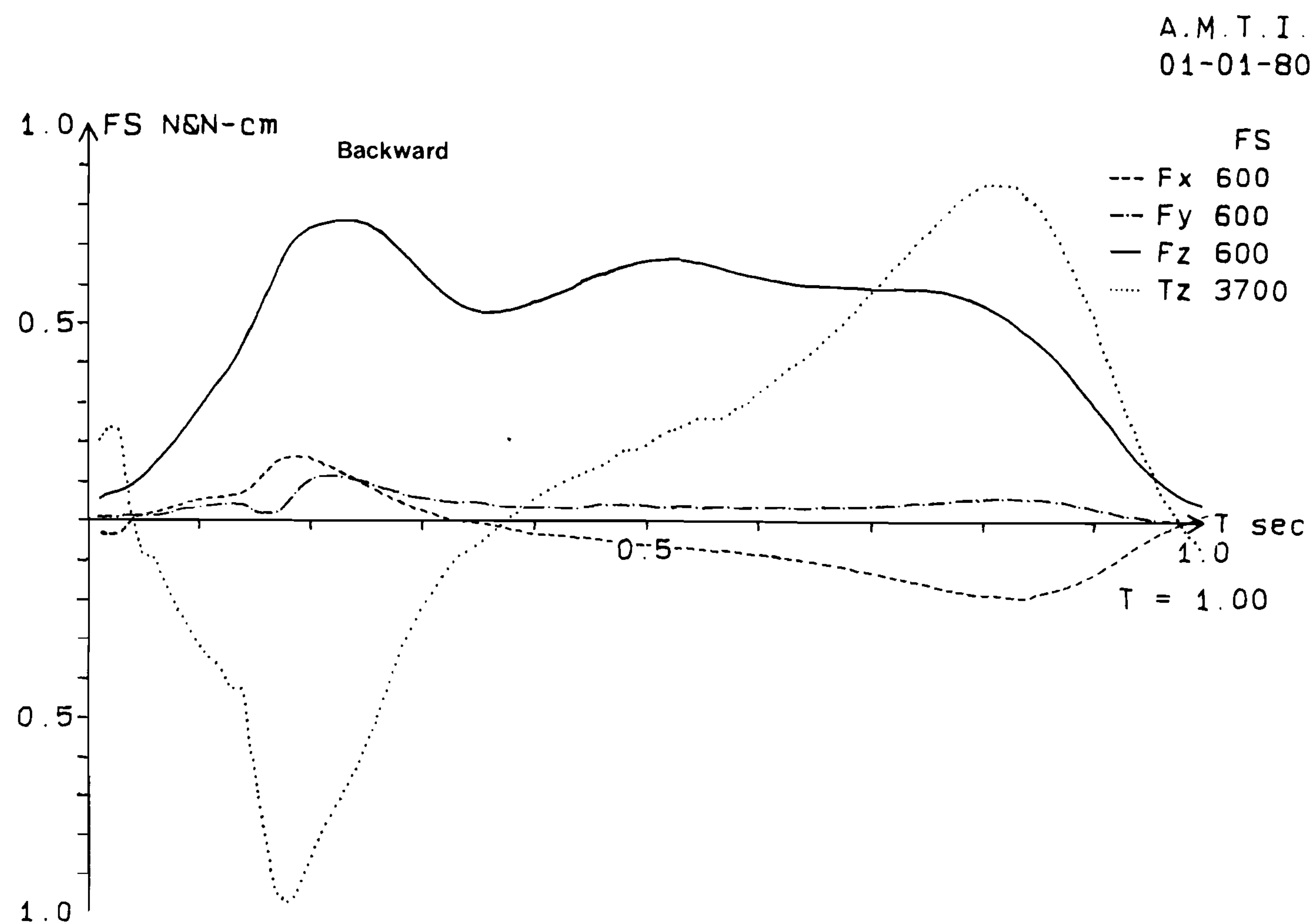

Fig. 7. False walking backward.

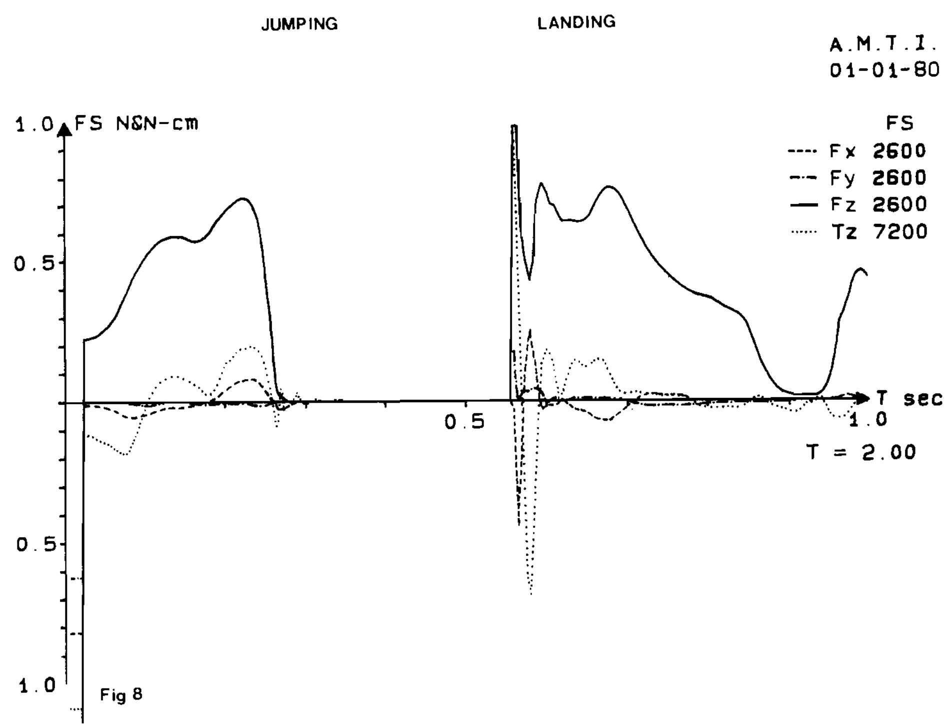
JUMPING
LANDING
A.M.T.I.
01-01-80
1.0
FS N&N-cm
0.5
0.5
1.0
Fig 8
FS
Fx 2600
Fy 2600
Fz 2600
Tz 7200
T sec
0.5
1.0
T = 2.00

Fig. 8

387

The complete videotape, therefore, contained a true movement of the walking forward, walking backward, jumping and landing; and four false movements of these four conditions. An EMG recording of the activity of the gastrocnemius, hamstrings, and quadriceps was obtained (Figure 5) and ground reaction forces measured from the same subject (Figures 6, 7 and 8).

Sixty subjects were selected from two classes at the University of Illinois at Urbana-Champaign in the USA. The videotape was shown to the class and asked their visual perception of the movements. The subjects observed the walking patterns initially with only the legs visible, and then with the entire body visible. Finally, the jumping and landing patterns were observed. A questionnaire was given to each subject. The subjects were asked to select one of two responses indicating whether or not (true or false) the movement pattern they observed was a true movement. The subjects were to indicate the certainty of their response with a scale from 1 to 7, with number 1 being not sure, and number 7 being very sure. If the subjects were unable to determine whether the movement was true or false, they were to then select a third choice (unable to tell).

RESULTS AND DISCUSSION

The responses from the questionnaires were evaluated as «right», «wrong» and «unable to tell» with respect to Chi-square criterion values. These criterion values were inputted to a computer and frequency distributions and Chi-square were obtained. Since 50% of the responses in any condition will be correct by chance, the null hypothesis could only be rejected if cell blocks in the Chi-square were larger than 50%. The correct responses were significantly ($p < .01$) different from chance for walking forward, but not for walking backward when the true movement was observed (see Table 1). Incorrect responses were significant ($p < .01$) for the walking backwards in all observed conditions (Table 1 and 2). Table 2 also includes responses to observation of the false movement of walking forward. For this condition, also the responses were significant at $p < .01$.

From these results one might state that for continuous skills, visual perception adequately transfers information to the observer regarding all walking forward patterns (including both the true and the false projected movements). This agrees with conclusions of previous researchers

TABLE 1
TRUE MOVEMENT: Walking Forward and Backward

	Response (%)		
	Correct	Incorrect	Unable to Tell
Walking Forward			
Legs and Whole Body	85.5**	10	4.4
Legs Only	85**	10.4	4
Whole Body Only	86.3**	9.6	4.2
Walking Backward			
Legs and Whole Body	50.2	42.9**	6.9
Legs Only	50	41.3**	8.8
Whole Body Only	50.4	44.6	5

** $p < .01$

TABLE 2
FALSE MOVEMENT: Walking Forward and Backward

	Response (%)		
	Correct	Incorrect	Unable to Tell
Walking Forward			
Legs and Whole Body	65.8**	29.6	4.6
Legs Only	65**	30	5
Whole Body Only	66.7**	29.2	4.2
Walking Backward			
Legs and Whole Body	39.2**	56.5**	4.4
Legs Only	39.2**	56.7*	4.2
Whole Body Only	39.2**	56.3*	4.6

* $p < .05$
** $p < .01$

TABLE 3
TAKEOFF AND LANDING: True and False Movement

	Response (%)		
	Correct	Incorrect	Unable to Tell
TRUE MOVEMENT			
Takeoff and Landing	45.8	42.5	11.7
Takeoff Only	45	41.7	13.3
Landing Only	46.7	43.3	10
FALSE MOVEMENT			
Takeoff and Landing	34.2**	56.7	9.1
Takeoff Only	26.7**	63.3	10
Landing Only	41.7	50	8.3

** $p < .01$

(Johansson, 1973; Cutting & Proffitt, 1982). In the case of walking backward, however, visual perception inadequately transfers information. This may be due to the observers unfamilarity with backward walking patterns. Therefore, the «right» and the «wrong» backward walking patterns may not be totally dependent upon visual perception. Conversely, since observers were able to distinguish between the projected true movement from the false movement in walking forward, this may be attributed to familarity of observing forward walking patterns in everyday life. Scully (1986) showed that expert judges in gymnastic scored higher in judging between relative and absolute motions than the novice judge. This also suggest that the perception of relative motion of a movement alone is not sufficient to successfully judge the gymnast. Instead, it is experience and background about movement execution that assist visual perception.

The responses of take-off and landing for both the true and false movement are depicted in Table 3. When the true movement was observed, no significant differences were obtained. When the false movement was observed, the correct responses were significantly different than that obtained by chance but in the negative direction. This would indicate that the number of responses did not even reach the 50% level (as would be obtained by chance). Since a discrete skill, such as jumping, is completed in a very short time frame, confusion may arise among the observers who are only relying on visual perception. However, Johansson (1976) concluded that vision is able to transfer information within 400 ms. It may be fair to suggest that quick movements require more than just relative motion observation and/or perception of kinematics; and that vision alone is not always able to adequately provide all the necessary information.

Ground reaction and muscle forces (via electromyography) were gathered (see Figure 5). In Figure 5 are the EMG activation patterns for both movements of walking forward and backward. Muscle activation occurs at different time sequences due to different muscle involvement when the direction of movement was reversed. Although the relative motion between walking forward and backward may be similar, the actual kinematic parameters are different (Kilani et al., in progress). This may be due to invariant features of kinematic parameters, as was hypothesized by Schmidt (1982) while in fact these parameters are variant in the absolute measure. Ground reaction forces were also different in all conditions (Figures 6, 7 and 8). In walking forward, the impact forces appeared to be lower than the impact forces in walking backward. Similarly, the take-off forces were larger than the landing forces for the same impulse duration. These findings enhance the hypothesis that although kinetic data are qualitatively different in all conditions by virtue of temporal pattern analysis, kinematics alone is not sufficient for determining kinetic differences and refutes the conclusion by Runson and Frykholm (1981).

The fact that true walking forward can be discriminated from the false walking forward pattern may be related to familiarity and previous learning of the forward walking pattern. This again supports the second hypothesis in this study and refutes Johansson's (1973) conclusion. In general, visual perception may aid coaches in some skills but not in others, and in slow movement patterns but not in fast ones. Therefore, it is suggested that further research be conducted to determine the type of kinematics patterns or movement cues which can be detected through visual perception. With this information, the coach may then focus, with the use of vision alone, on some of these cues thereby enhancing his or her coaching effectiveness. Without this information, a complete biomechanical analysis would be required to detect inefficient performance. This, in turn, would require the use of equipment more sophisticated than a simple videography system.

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