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Randall L. Jensen
Northern Michigan University

RELIABILITY OF A NEW LOWER EXTREMITY MOTOR CONTROL TEST: DOT DIAGRAM

Johnathan E. Lawrence and Randall L. Jensen

Department of Health, Physical Education, and Recreation
Northern Michigan University, Marquette, MI, USA

Nine alpine competitors (age = 15.4 ± 0.9 yrs) were suspended by their axillary region and moved their feet in a self-selected pattern to four markers on the ground. Three-D video analysis determined the segment length between the great toes of the right and left foot during a self-selected pattern. Feet were lifted from a center starting point, moved in one of four directions, and then returned to center before starting the next movement. Six trials over two days (3/day) were recorded with reliability (ICC) estimated for the segment lengths between feet. The ICC ($p < 0.05$) values for the trial duration, maximum, minimum, and average segment lengths were R = .976, .731, .916, and .951, respectively. The test was found to be reliable, although limited subjects were tested. We suggest the test should be pursued to indicate validity of lower extremity motor control to sport performance.

KEYWORDS: kinematics, movement control, alpine skiing, athletic stance

INTRODUCTION: Many sports such as alpine skiing, speed skating, and ice hockey require highly precise lower extremity motor control for high performance. Klika (1995) conducted many physiological and motor control tests to correlate performance in such variables to performance in alpine skiing. Unfortunately, the testing of these variables has not been able to predict performance. While it may be known that most power and endurance sport performance is related with an increase in strength, higher lactate threshold, and oxygen utilization, the prediction of highly motor skilled sport performance may not be possible using such parameters. Sports of high skill may require coordination and finely tuned motor control testing to assess such performance prediction.

Previous research has determined variability of motor control. The level of motor control varies with age (Roncesvalles et al., 2001), fatigue (Johnston et al., 1998), type of movement (Fukushi & Ohtsuki, 2004), and training. Christou, Zelent, & Carlton (2003) found larger variability in lower extremity than upper extremity force movements that involved multiple joints. This information might suggest that tasks with the lower extremities can be accomplished in multiple ways. Fast skiers may not move lower limbs exactly the same, however, it could be possible that fast skiers move their lower limbs more consistently.

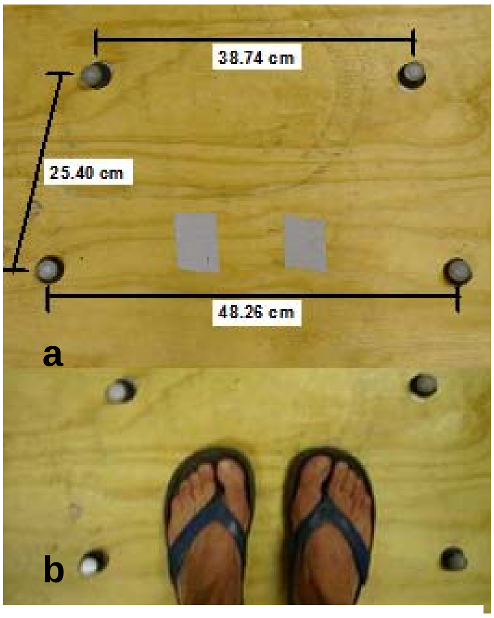
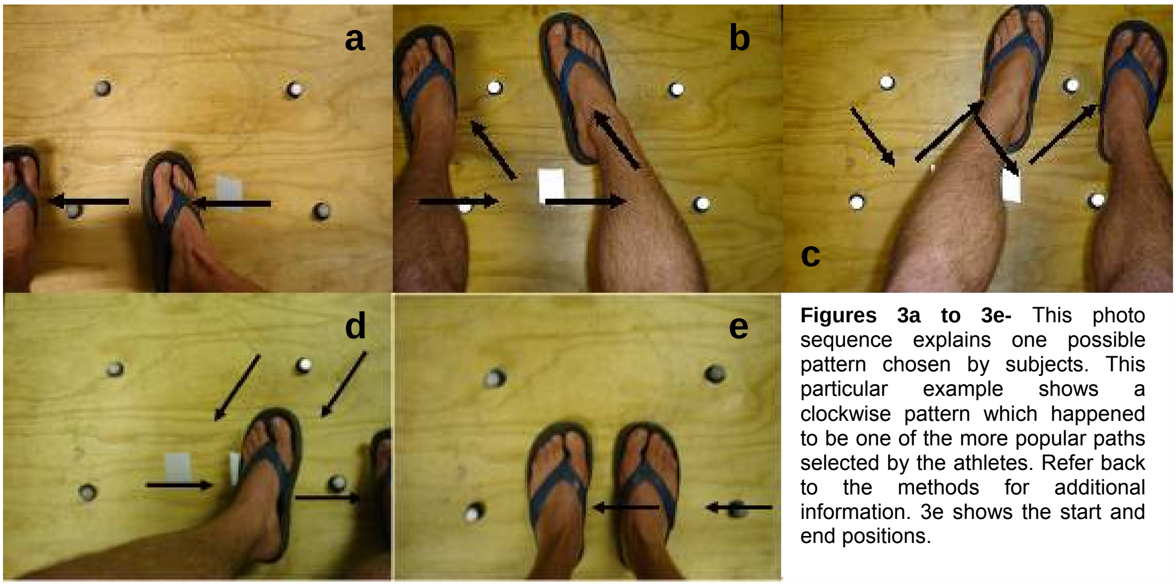


Figure 1a- Dot Diagram board with distances between markers. Reflective tape provides a start, home, and ending position for the feet. **1b-** Dot Diagram with feet resting at the

Skiing requires immense coordination of the lower limbs and the ability to overcome great forces simultaneously. O'shea and Larsson (1990) describe good skiing as the ability to make short, round, exact turns under any condition. Control and independence of lower limbs are valuable assets in skiing, although the ability to maintain a consistent and controlled lateral foot stance may be of importance to maintain equal turning radius, correct weight distribution of both skis, and balance during a turn. A specific motor control test may indicate which athletes have the ability to maintain a consistent lateral stance described by Lemaster (2004).

When implementing a test, the reliability of the test is important to insure that the responses of the subjects are consistent and able to be replicated. Therefore, the purpose of this study was to test reliability of high school aged alpine ski racers performing a new lower extremity motor control test for a potential avenue of performance prediction. The lateral distance of feet during ski racing is a commonly analyzed portion of the technique (Lemaster, 2004) and therefore the reliability of segment length between the feet was analyzed within this research.

METHODS: Approval for the use of human subjects was obtained from the institution prior to commencing the study. Nine high school alpine skiing athletes (mean ± SD: height = 166.4 ± 7.2 cm, weight = 62.6 ± 4.3 kg, age = 15.4 ± 0.9 yrs) volunteered to partake in all aspects of the study. A warm-up session was implemented with five minutes of cycling at a self selected easy to moderate intensity. Static stretching, targeting the lower limbs and hip muscles, was completed following warm up. Subjects were verbally instructed on proper technique of test. No practice trials were allotted for the purpose of analyzing a potential learning effect. The Dot Diagram consists of a board placed on the ground with four reflective balls placed in a trapezoid, see figures 1a-1b. Subjects rested their axillary region on a cross bar that placed them in a squat position, see figure 2. Another cross bar was placed in front of the subject for a handle to grab or rest forearms against for support.
The start position began with feet resting on the board in the middle of the trapezoid. The subjects were instructed to pick a self-selected pattern; an example is seen in figures 3a-3e. The beginning and end of the movement are seen in figure 3e. Subjects were instructed to move from the start to one of the markers, back to start, to another marker and back to start again until feet were directed over all makers. Both feet were lifted and moved to a marker, without touching the ground. The subjects then moved their feet back to the start, without touching the ground, and continued to move their feet to a different marker. The trial began when the right foot came off ground and ended when the foot first touched the ground at the end of a trial. A total of three trials per day on two consecutive days were recorded for a total of six trials. Subjects were instructed to use their original choice of specific pattern for all trials (refer to figures 3a-3e for an example pattern).



Figures 3a to 3e- This photo sequence explains one possible pattern chosen by subjects. This particular example shows a clockwise pattern which happened to be one of the more popular paths selected by the athletes. Refer back to the methods for additional information. 3e shows the start and end positions.

Only one direct segment length from the left great toe to the right great toe was used. The maximum was the greatest distance between these toes at any time during the movement and the minimum was the shortest distance. Averages were derived from the whole trial as described above and trial duration was calculated by counting frames recorded by cameras.
Data were collected at 60Hz using two Canon Optura 20 cameras (Canon Inc., Tokyo, Japan), with an angle of roughly 100 degrees, and synchronized with a Remote Video Synchronization Unit (Peak Performance Technologies Inc., Englewood, CO, USA). Digitizing and kinematic analyses were accomplished via Peak Motus v8 (Peak Performance Technologies Inc., Englewood, CO, USA). The segment length data was calculated and the

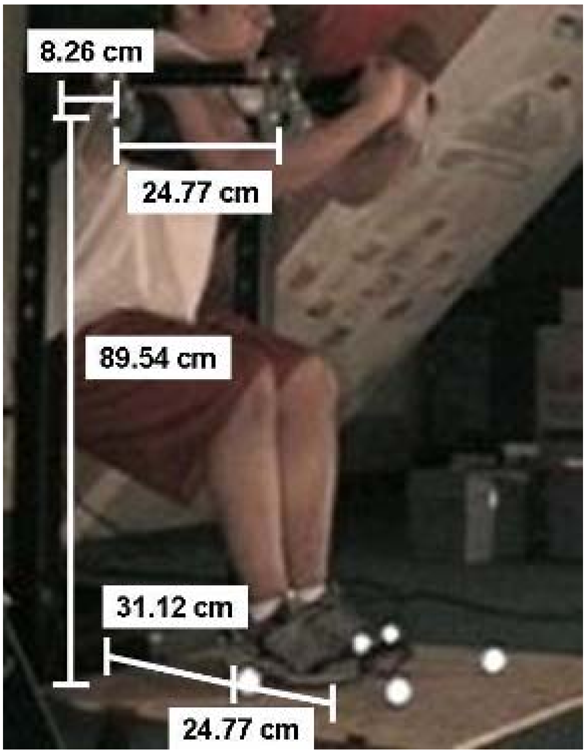


Figure 2- Subject resting before trial. The figure indicates how the subject was suspended. These distances were used for all subjects.

Variables	ICC	95% confidence interval	ANOVA
Minimum	.916**	.788 - .978	.353
Maximum	.731*	.319 - .930	.383
Average	.951**	.875 - .987	.121
Trial Duration	.976**	.941 - .994	.201

* Moderate
** Strong

Table 2
Means and standard deviations (STD) for the segment length between great toes of the right and left foot during each trial. (N = 9)

Trials	Mean	STD
One	.090	.026
Two	.084	.024
Three	.082	.022
Four	.091	.018
Five	.095	.017
Six	.092	.021

trial duration, maximum segment length, minimum segment length, and the average length were treated. Statistical treatment of the data was performed using Reliability Analysis (SPSS, v12.0, 2002). An Intraclass Correlation and Repeated Measures Analysis of Variance were performed across trials.

RESULTS: Although trial duration did vary across subjects from 176 to 443 frames (293 to 738 milliseconds), the trial duration Intraclass Correlation Coefficient (ICC) and 95% confidence intervals indicated that duration was highly reliable (.976 at $p < 0.05$), see Table 1. The minimum segment length ranged from 0.0309 to 0.0779 meters and also indicated moderate to strong reliability (ICC .916 at $p < 0.05$). Maximum segment length provided the largest variability with a range from 0.0759 to 0.2878 meters and thus only showed low to moderately consistent segment lengths (ICC .731 at $p < 0.05$). The average segment length ICC value was .951. Average segment length for each trial ranged from 0.0570 (low) to 0.1476 (high) meters with standard deviation range of 0.0049 (low) to 0.0354 (high) meters. Descriptive values for the segment lengths of each trial can be seen in Table 2. Total percent error was calculated by $(x_{max} - x_{min}) / x_{max}$ and was less on day two, but negligible. Total error for trials 1, 2, & 3 (day 1) in regards to trial duration, maximum segment length, minimum segment length, and average segment length was 10.7%, 31.7%, 16.2%, and 18.1% respectively. Trials 3, 4, & 5 (day 2) had a total error of 9.7%, 30.1%, 15.6%, and 11.7%. Calibration frame error was ≤ .142% for both days.

DISCUSSION: The Dot Diagram was found to be a reliable test with a limited number of subjects; however, due to the limited number of subjects, further study with additional subjects is recommended. The trial duration and minimum segment length were the most consistent. However, because the feet can only get as close as touching this value may have had more variability if the subject were instructed to not let the feet touch. It was seen in some subjects that the control of the movement was assisted by adducting the legs and moving them as one limb with feet touching. Controlling for feet touching should be implemented as ski racers usually do not allow feet to touch one another during competition as the base of support becomes too narrow. Thus to determine the subject's consistency and accuracy of movement similar to alpine skiing, the subject should be instructed to not allow the feet to touch.

The average and maximum segment lengths seem to provide the most information. Subjects were consistent overall in the movement; however, the 95% confidence interval indicates there is some variability, particularly for the maximum distances. This is most likely due to their inability to be consistent with the maximum lengths when the feet were apart from another.

Hypothetically the subjects who best maintain the segment lengths with consistency may be the better performers while competing. However, when both lower limbs are extended to the same side laterally, the more lateral leg extends at the knee and hip to a greater extent than the medial leg. Although the medial leg is also moving laterally, this leg has more flexion in the knee and hip. An anterior view of the width of the feet may show a wider stance (Lemaster, 2004) and the direct distance between great toes is longer. With a closer look at the longitudinal axes, the width of the athletic stance or lateral foot distance may be the same (Lemaster, 2004). Therefore, the variability in maximum length may possibly be an advantage in performance as the subjects were told to place both feet over one marker. The four markers used may need to be added to and repositioned to have left and right foot markers so subjects can have a consistent target rather than one general marker for both feet. Validity studies are encouraged to be performed, although further reliability work may also be needed.

In allowing subjects to choose a self selected pattern, it is possible that a given pattern may provide less variability. Therefore, a set pattern for all subjects may need to be implemented for performance prediction. One example of the patterns chosen was shown in the methods (refer to figures 3a-3e), however, the selected paths varied by personal preference.

CONCLUSION: The current study indicated that the new Dot Diagram is fairly reliable test with the limited amount of subjects used. A larger sample size and minor adjustments in the control might result in less variation across subjects, providing better reliability. More markers placed on the ankle, knee, first metaphalangeal joint, and fifth metaphalangeal joint would provide a great deal of information, such as the horizontal plane of the foot sole. A direct segment length may not provide the best possible analysis of horizontal distance when feet are both laterally to same side as the inside leg has more flexion of the hip and knee. The direct great toe segment length may be longer and the lateral distance between the longitudinal axes of the lower limbs may still be the same. However, an examination of the consistency of equal foot distances during the portions of movement near the “start” position and smooth but consistent increases and decreases near markers may provide additional information. Future studies may implement the use of the Dot Diagram or variations of it to potentially meet the goal of sport performance prediction.

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