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ORIGINAL ARTICLE

Assessment of Correlation between Electrogoniometer Measurements and Sports-Specific Movement in Karate Elites

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Authors' Contribution

- A Concept / Design
- B Acquisition of Data
- C Data Analysis / Interpretation
- D Manuscript Preparation
- E Critical Revision of the Manuscript
- F Funds Collection
- G Approval of the Article

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Abstract

Purpose: **To examine the intra-rater reliability of knee movement data in sagital plane obtained from electrogoniometer (EGM) in a basic, sport-specific task of karate.**

Methods: **A total of 23 elite karate athletes (13 females and 10 males; mean age of 16.10±1.26 yrs) participated in this study. The task was defined as performing three consecutive Zenkutsu-dachi in two sessions. The used EGM was a twin axis of Biometrics company. EGM curves were plotted in MATLAB software separately. The indices of three points in the plots corresponding to extremes of flexion and extension of knee in the first dachi were determined. There was also another (forth) point which was not in extremes of movement. As it was repeated in all curves, it was perceived as a biomechanical event and was assessed. The phases of movement between the points were scaled between 0 to 100% of activity.**

Results: **Repeatability of the forth point index was assessed by intraclass correlation method. Intraclass correlation of the ratio in the first testing session was 0.666 and in second was 0.448. The interval between points were considered as phases of movement. After determining three phases of dachi, it was shown that these phases pertained a specific ratio of the total plot which were 48%, 36% and 16% of total respectively.**

Conclusion: **Dachi could be divided into three distinct phases; each of them should constitute a specific percent of the total in an elite athlete.**

Key Words: Electrogoniometer; Dachi; Karate; Kinematics; Reliability

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INTRODUCTION

Kinematic studies of basic movements of each sport helps sports people to improve their performance and their physician to discover the etiology of injuries. Stances constitute a great part of karate training and competition. Many different stances are practiced in karate, each used to create power, flexibility and movement. In this investigation we studied dachi as the basic karate stance in kata [1]. Kata is the performance of a number of consecutive techniques, which indeed is combat with imaginary opponents.

Zenkutsu-dachi which is addressed in this paper is the dachi which needs the highest level of knee flexion. Although the specifics of the stance vary by style, overall it is similar to a lunge. This forward stance is one of the most common stances used in karate. Zenkutsu-dachi is a long frontal stance where the weight is mostly on the front leg, the rear leg is completely straight at the knee and extended back. The front foot is placed frontal (toes facing forward), the rear foot is turned out 30 degrees; and the heel of the rear foot rests on the ground. Theoretically, positioning the rear foot parallel to the desired direction of body forward motion would be more effective than turning

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the foot outward. In the zero-degree foot position the whole length of the foot (heel to toe) can be used as a lever. This would give the foot more time to apply force against the ground. The feet are shoulder-width apart. The speed of performing the task is different in different athletes but overall it is performed in a fraction of a second.

The purpose of the stance is to train musculoskeletal alignment that adds as much mass of the earth to a strike as possible. The stance allows a great deal of power generation forward [2,3].

Knee joint angle measurements are performed as a part of joint assessments and address treatment outcomes in elite athletes [4,5]. Standard electrogoniometers (EGMs) are often used in clinical settings to quantify static and dynamic knee joint positions.

The reliability of knee joint position assessment using EGM was studied by Piriyaprasarth et al. They used a flexible Biometrics EGM which was the same EGM addressing in our study to investigate the inter- and intra-tester reliability of knee joint angle measurements. They concluded that with a standardized protocol, reliable measures of knee joint angles can be gained in standing, supine and sitting by using a flexible goniometer [6].

Validation of biometric flexible EGM for measurement of Joint Kinematics was investigated by Rowe PJ et al in 2001.They used the device for a series of controlled experiments and compared the result of EGM with motion analysis system data. They concluded that with appropriate application of the device, it is valid and accurate in clinical setting [7].

In another study, Walker and Myles (2001) used EGM to measure the range of motion of the knee in patients with knee osteoarthritis and healthy subjects. The same biometrics flexible EGM was applied in their investigation. They concluded that electrogoniometry of the knee provides a reliable, accurate and objective measurement of knee function [8].

In other study, Edgar D demonstrated excellent intra-rater and inter-rater reliability and measurement of clinically relevant change.Therefore; the study result showed that assessing joint range of motion (ROM) with a goniometer can provide accurate and objective measures [9].

In 2010 Bronner investigated reliability and validity of electrogoniometry measurement of lower extremity movement. Their project ran two experiments; in the first EGM accuracy was compared to a digital protractor and in the second to a criterion measure, which was motion analysis recording in dancers. In both of them Pearson’s Product – moment correlation (r=0.98) was high [10].

Usefulness of Digital goniometric measurement of knee joint excursion in clinical and research setting was evaluated by Cleffken et al in 2007. They determined the reproducibility of active and passive range of motion of knee and concluded that clinical and statistical differences in research settings are not a true difference but are attributed to measurement error [11].

In another study in 2010 Carey described reliability, validity and clinical usability of a digital goniometer. The study demonstrated adequate concurrent criterion-related validity as a tool for assessment of joint range of motion and equivalent inter- and intra-rater reliability in utilization by clinicians [12].

The measurement tool has also been compared with other clinical instruments. Yaikwawongs et al compared the reliability of knee ROM measurement using a digital goniometer with measurement from roentgenographic picture, in 2009. They found the digital goniometer to be a reliable tool for measuring knee ROM in flexion and extension planes [13].

In all studies mentioned, the reliability and validity of EGM were evaluated but there is no study to investigate the correlation and concurrency of goniometer data with a sport-specific movement; therefore we decided to assess the intra-rater reliability of data of knee movement in sagital plane obtained from EGM in a basic, sport-specific task of karate.

METHODS AND SUBJECTS

The study population consisted of 23 elite athletes, 13 female and 10 male athletes were invited to the national junior and cadet team camp. This work was the first step of a longitudinal study that examines the changes in biomechanical properties of performing a sport-specific task, dachi, in elite karate players.

Measurements were done at the beginning and at the end of a training course, which was held to make the young athletes ready to participate in the Asian Cup of 2011.

Any athlete with a history of acute injury or orthopedic pathology in the lower limbs, patella subluxation, ligament or meniscal injury or abnormal radiologic finding in lower extremity was not included in the study.

In the beginning, test procedures were fully explained to athletes. People who were interested in participating in the study received and completed the written informed consent. All athletes were told that they had the right to withdraw from the study at any stage of the investigation. The Research Ethics Committee of Tehran University of Medical Sciences approved the study (Grant number: 90-03-30 13332).

The EGM used in the study was a twin axis goniometer SG 150 of Biometrics company. According to the producer, the accuracy of measurement is ±2° over a range of ±90°. The device was connected to the surface electromyography Mega (ME 6000) to record data.

Testing session started with a 10-minute warm-up by a stationary bike and any other exercises of quadriceps and hamstring muscles according to athletes' preference. Then, the EGM was placed on lateral part of right knee and its center was settled on the femoral condyle. One arm of EGM was parallel to the long axis of the femur and the greater trochanter and the other arm was parallel to the leg and lateral malleolus. The device was attached to the lower limb by a double-sided adhesive stick. In order to minimize motion, elastic bands were wrapped around the lower limb and the arms of the EGM.

In the zenkutsu-dachi position the knee and hip of the front leg are flexed. The rear leg is extended at the knee with the hip joint in outward rotation. The rear foot is dorsiflexed at the ankle and directed forward and outward. The outward rotation of the ankle is between 20 and 45 degrees. Weight distribution on front and rear feet is 60 and 40 percent. The length of the stance is twice the width of the Athlete's shoulders. During the forward motion in zenkutsu-dachi the rear leg slides forward and at the same time the fist is accelerated as the forearm extends at the elbow and the arm flexes at the shoulder (Fig. 1).

The task was defined as performing three consecutive Zenkutsu-dachi, in order to comply with the tune of dachi in kata. In order to familiarize the participants with the procedure they were permitted to perform the task as many times as wanted.

At the beginning, the athlete posed the Zenkutsu-dachi while the left foot was located forward. With hearing the command the task was executed at the athletes' usual pace. Data was recorded simultaneously in Megawin software version 2.4, provided by the manufacturer. Sampling rate was 1000 Hz and the data was recorded 3 seconds before the beginning and after the end of the task. Data of both sagittal and frontal planes of knee movement was obtained; although the sagittal plane plots were analyzed [14]. Signal accuracy and possibility of the presence of noise was viewed at the end of each record, and if there was any abnormality the test was performed once more. The karate athlete repeated the task until three acceptable signals were recorded. Finally, the data was saved in the binary file format for further analysis.

In processing, each file was opened in MATLAB software and EGM curves were plotted. Points corresponding to extremes of flexion and extension of knee in the first dachi were determined, and each received a number as is shown in Fig. 1. There was

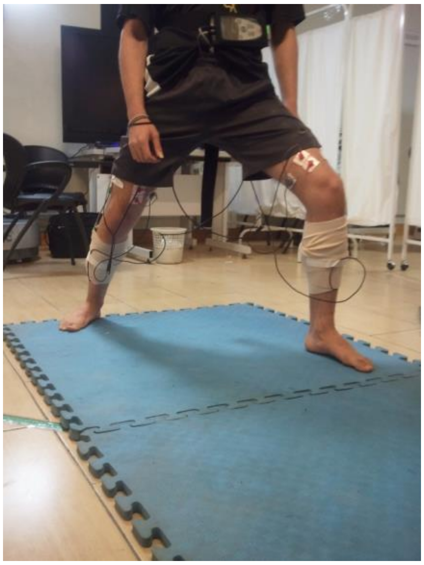

Fig. 1: Dachi task

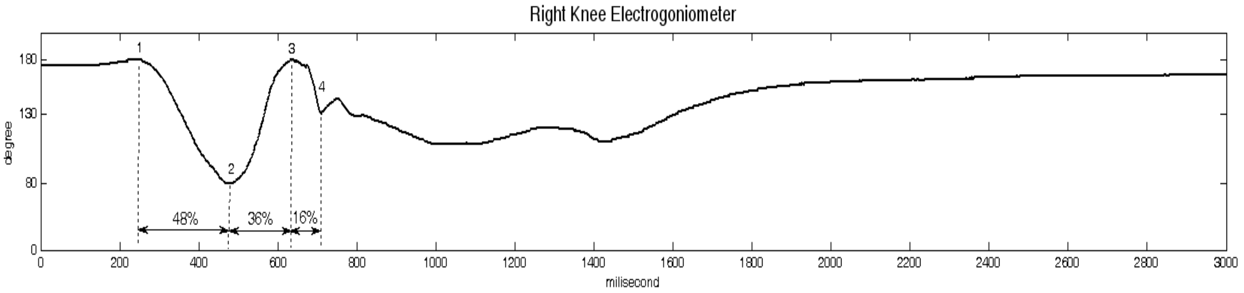

Fig. 2: One of the plots which shows different Phases of dachi

also another point which was not in extremes of movement. As it was repeated in all curves, it was perceived as a biomechanical event and was assessed. The points were scaled between 0 to 100% of activity [15]. The rest of the analysis was performed by SPSS version 14. Confidence level for all tests was set at 0.05.

Comparing the dachi movement pattern using the Wilcoxon Signed Ranks Test in the beginning and end of training camps, there was no significant difference in each phase of movement. This suggests that the biomechanical models of the karate- specific movement at the beginning and end of the study were similar. Thus correspondence of EGM data with movement phases has acceptable reliability and validity.

RESULTS

The mean age of participants was 16.10±1.26 (range: 14-18) years and the mean Body Mass Index of the athletes was 20.86±0.40. They all participated in a series of training sessions for six weeks. The sessions were held twice a day for 4 days and once a day for the other three days of the week. Each session lasted 90 minutes excluding warm-up and cool-down. Therefore the volume of training was 990 minutes per week (16.5 hours/week).

A typical plot of dachi is shown in Figure 2. There are three distinct points in the plot that correspond to the beginning of the movement, maximum flexion and return to extention respectively. There also exists another distinguishable point, probably corresponding to a specific biomechanical event.

Each point in the curve represents the spatial position of knee in sequence of event sampling. The index of each point was extracted and the intervals between points were considered as phases of movement. The phases were scaled between 0 to 100% of activity. The results are presented in Table 1, and in separate groups of males and females in Table 2.

According to normality test of Kolmogrov-Smirnov and histograms, proportion of phases of dachi movement in percent had a normal distribution overally and in female and male groups.

Considering the sequence of movement in dachi and its concordance with appearance of a notch in EGM curve, it would be supposed that this specific biomechanical event might illustrate right foot contact

Table 1: proportion of each phase of Dachi in percent

Phase	Beginning of Training			After 6 weeks of training		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Phase 1	48.13 (14.24)	28	89	48.14 (10.43)	26	61
Phase 2	35.74 (11.31)	13	58	33.72 (9.11)	13	51
Phase 3	16.13 (7.27)	4	27	18.14 (9.21)	4	34

SD: Standard deviation

Table 2: proportion of each phase of Dachi in separate groups of males and females

Phase	Beginning of Training				After 6 weeks of training			
	girls		boys		girls		boys	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Phase 1	52.42 (15.91)	28-89	42.02 (8.77)	31-56	50.05 (7.26)	39-61	45.01 (13.48)	29-66
Phase 2	34.72 (12.39)	13-59	37.71 (9.76)	24-56	31.66 (9.58)	13-47	37.47 (9.93)	26-58
Phase 3	12.86 (6.55)	4-24	20.27 (6.16)	7-27	18.29 (9.47)	7-34	17.52 (10.26)	5-35

SD: Standard deviation

with the ground. For testing reliability of the point (point 4 or right foot contact), we defined two parts of the plot, the first phase was considered as a constant part of the equation (d1) and the distance between maximum flexion of knee and point 4 as under review part (d2) as is shown in Fig. 3.

In order to assess the repeatability of the forth point, we were supposed to assess the index of the point by the statistical method of intraclass correlation [16]. As the tasks were performed in different time spans, and as the speed of the athlete could not be calculated by the present data, we calculated the ratio of d2/d1 and the result was reported in percent. In order to minimize the effect of the variation of temporal parameters of performing a dachi on results, d2/d1 ratio was selected instead of d2 part for further analysis. Since each participant performed the task three times in each testing session, six ratios were calculated for each athlete.

Intraclass correlation of the ratio in the first testing session was 0.666 and the number for the second testing session was 0.448.

DISCUSSION

In the broad spectrum of technical elements that athletes encounter in Karate, there are initial positions which are considered as basics and called postures. A posture is a fixed body position, from which accomplishing most defense or attack is allowed. Any posture comprises of a static position, in which the body position is preserved and a dynamic start that implies a change of that position through the movement.

There are no precisely defined criteria about value of joint angles and the moments of time during a task which those who exercise should satisfy. So considering a criterion for regularity of a posture which is being performed will be an advantage beside a master's observation.

If correct posture is captured by EGM assessment, we can conclude the regularity of posture not only with our inner state and physical body, but also with definition of ration between segments. It is necessary to have in mind that for a physically regular posture it is

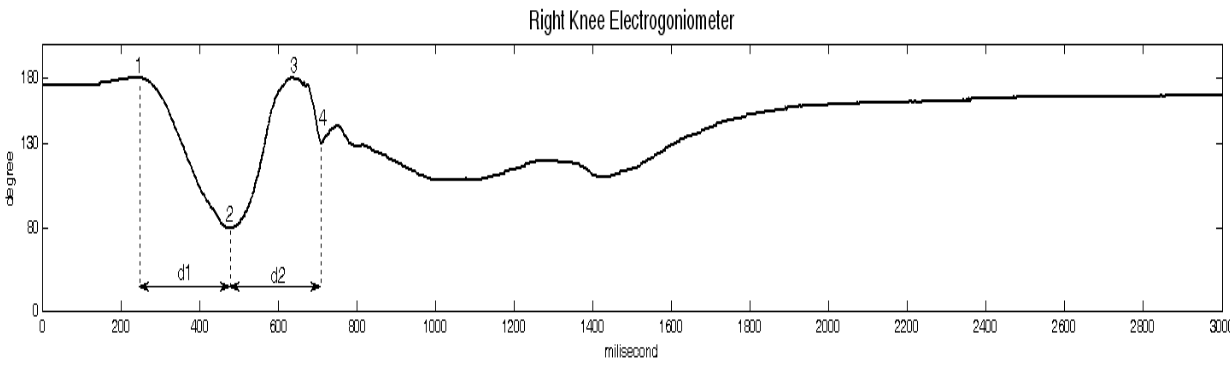

Fig. 3: The same plot as Fig. 1 which shows the parts of calculated ratio

very important to constitute a morphologic and dynamic pattern, on which individual characteristics of posture are defined for everybody independently.

In the study, we intended to describe the kinematics of dachi (one of the basic movements of karate) by using data obtained from an EGM placed on the right knee.

Reliability of biomechanical measurements of the lower extremities was evaluated by Van Gheluwe et al in 2002. They demonstrated high intra-rater ICCs (>0.8) for most rater and measure variables [17].

Atkinson and Nevill evaluated statistical methods for assessing measurement error (reliability) in variables relevant to Sports Medicine. They concluded that methods based on correlation coefficients provided a relative reliability and must be inferred cautiously because these methods are highly influenced by the range of measured values in sports [18]. Therefore, the ICC (3,1) was used in our study for reliability of the kinematics event. The reliability was reported in our study in two steps, which were 0.666 and 0.448 respectively.

A systematic review included 17 studies investigating inter-rater reliability of passive movements in lower extremity joints has been done by van Trijffel et al in 2010. They concluded that inter-rater reliability of measurement of passive physiological movements in lower extremity joints is generally low [19].

The same systematic review about inter-rater reliability for measurement of passive physiological range of motion of upper extremity joints was done by van de Pol and van Trijffel. They concluded that inter-rater reliability of measurements of passive movements in upper extremity joints varies with the method of measurement. In order to make reliable decisions in clinical practice, they recommended using goniometers or inclinometers [20].

The EGM could be implemented in surveys of different joint movements including the knee. In 2011 Milner et al used ICC for test-retest reliability of knee biomechanics during stop jump landings. Peak angles and moments were similar between sessions. Overall reliability within a session (ICC=0.63-0.88) and between sessions (ICC=0.68-0.96) are acceptable [21]. Although there are differences in applied methodology, we have the same analytic implementation in the study.

In another study investigated by Hunter and Marshall in 2004, they assessed the reliability of biomechanical variables of sprint running. They applied video and ground reaction force in maximal-effort sprints and the reliability for a single score was calculated for kinematic and kinetic variables. The reliability for the average scores was predicted from the reliability of a single score. They concluded that with considering the average score of multiple trials as a measurement of interest, the reliability of all variables was improved [22]. In our study the ICC (3,1) reduced from step one to two in six test sessions. We do not have any deduction explaining this reduction. This inferred information should be addressed in further studies.

Fong and Blackburn in 2011 illustrated ankle-dorsiflexion displacement during landing in a descriptive laboratory study. They assessed Landing biomechanics via an optical motion-capture system interfaced with a force plate and Dorsiflexion Range of Motion was measured using goniometry. Pearson Product- moment correlation was used to evaluate relationships between dorsiflexion ROM and each biomechanical variable. They concluded that greater ankle dorsiflexion ROM was associated with greater knee-flexion and smaller ground reaction force has consistency with reduced ACL injury risk [23]. The study implies the importance of implementing two or more biomechanical assessment tools in order to measure a motion comprehensively. Therefore, we recommend further study implementing gold standard methods, e.g. video analysis, to improve our knowledge of the kinematics of this sport-specific movement.

We could not find any investigations to study the correlation of EGM curve with different phases of dynamic movement of lower extremity during the sports specific task of dachi.

In comparison to the present study, as there is no previously reported cut off point with our results, we cannot have a firm conclusion about the importance of the obtained ICC.

We found the correlation between point 4 of EGM curve and specific movement in dachi with acceptable ICC in context of a larger study addressing electromyographic activation pattern of muscles surrounding the knee in karate elite. Although this finding has limited clinical application, it indicates the role of goniometer measurement in evaluating dynamic movement in athletes.

Future study should be done to correlate the kinematic motion, joint contact stress and the vastii activity in athletes of different sports.

CONCLUSION

Dachi, a basic stance of karate, can be divided into three distinct phases; each of them should constitute a specific percent of the total in an elite athlete. A fair correlation was found between an indentation of EGM curve and a specific biomechanical event, possibly right foot ground contact in dachi movement with acceptable reliability (ICC=0.448). There is doubt about reproducibility of this method and it needs further investigation**.**

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Conflict of interests: None

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