PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Reliability and concurrent validity of Iphone® level application for measuring lower limb active flexion and extension range of motions in physical education students

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Background and Study Aim The aim of this study was to analyse reliability and validity of accelerometer-based Iphone® Level application for measuring lower extremity active flexion and extension joint range of motion.

Material and Methods Thirty physically healthy students enrolled in sport sciences (11 males, 19 females, 21.2±1.5 years, Body mass 64.4±10.0 kg, Height 1.68±0.8 m, Fat percentage 21.2±7.8 %, 22.5±2.6 kg/m^2) participated in the measurements of hip, knee, and ankle joint range of motion twice through Universal goniometer and Iphone® Level applications. The same experienced measurer carried out blind study of plantarflexion, dorsiflexion and knee flexion/extension, hip flexion/extension joint range of motion three times for each measurement methods and the other researcher recorded the results. For simultaneous validity analysis Pearson coefficient of correlation was used to decide the level of adaptation between the two intraclass correlation coefficient and Cronbach's alpha values. Bland-Altman graphics were utilized for level of agreement between these two different methods.

Results The results of Pearson coefficient of correlation analysis revealed a positive correlation between the measurement values of joint range of motion performed through Universal goniometer and Level App (r^2 = 0.44-0.94, p <0.05). Bland-Altman graphics showed a good agreement among Cronbach Alpha values and intraclass correlation coefficient in the confidence range of %95, and universal goniometers and Level App application.

Conclusions: The results of this study revealed that goniometric measurements using Iphone® Level App is a good reliable method for measuring lower extremity active range of motion compared to universal goniometer.

Keywords: joint motion, goniometry, smartphone applications, validity

Introduction

In the 21st century, technological developments have appeared in many areas of usage, including the world of sports. Increase in the use of technology in the world of sports has led to developments including online application, smart TVs, and mobile phones [1].

Technological advancements in branches and different areas in the world of sports have become a part of sport and are seen as solution-oriented assistants by both amateur and professional athletes [2]. With the introduction of sports to human life, various applications have been used for physical activities in daily life [3]. To understand the capacity of movement and evaluate it, functionality of the structures supplying the movement should be known. Thanks to advancing technology, measurement of movements in activities has become easier and joint range of motion (ROM) known as capacity of movement has come into prominence. ROM is known as joint arc originating towards one or more joints [4]. Functionality in amount of joint ROM is directly proportional with attendance in daily life activities [5].

In clinical and scientific research, the most common angle meter is universal goniometers (UG) for the measurement of joint ROM. UG is the most common one due to its ease of use, attainableness, cost, and reliability [6]. Despite its common use, it might reveal inconsistent measurements since in hinge type joint such as knee and elbow cannot be marked properly [7]. Moreover, stabilization of the joint is difficult because hands are used during the measurement, which contributes to increased failure rate [5]. In addition, lack of experience and knowledge in positioning the joints may increase the failure rate. To minimize the failure rate in UG using smart phones is at the forefront. Nowadays smart phones have been equipped with many applications such as accelerometer, manometer, and gyroscope [8]. While applications are providing joint ROM measurements to be easier and faster day by day, usage, portability, and data collection also get easier.

Clinicians and scientific research have stated that UG ais supposed to give clearer results owing to reliability and validity of smart phones in measuring joint ROM. Research has compared UGs and smart phone applications. For example, Cox, et al., [9] stated in their research that Clinometer application can be a valid alternative for ankle plantar and dorsal flexion. Milanese, et al., [10] indicated that in knee flexion, KGA and UGs are both reliable and

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valid for measurement. In addition, Romeo-Franco, et al., [11] found that MyProprioception application is able to be used for different joint motions in knee and ankle. Charlton, et al., [12] stated that smart phone applications are suitable for usage in different range of motion of hip. Keogh, et al., [7] mentioned that smart phone applications for different joint range of motion measurement can be observed and utilized. In the light of information in the literature, the main aim of this study is to analyse interclass reliability and concurrent validity of level application on Iphone® smart phones with universal goniometer for active joint range of motion.

Material and Methods

Participants.

Prior to data collection, power analysis using Power Analysis and Sample Size (PASS, Version 2021, NCSS, Kaysville, Utah, USA) programs. was conducted to determine the minimum number of participants, before When Alpha (α) value is determined as 0.05, power value (1-β) is 0.95, the confidence level of agreements (LoA) is 0.9, the confidence level of the confidence intervals about the LoAs is 0,9, the number of participants is appointed as 31. Rate of waste was considered as 10 % and the study included 34 participants. During the research, four of the participants dropped out of the study of their own accord with various reasons. Eventually 30 students (11 males, 19 females 21.2±1.5 years, Body mass 64.4±10.0 kg, Height 1.68±0.8 m, Fat percentage 21.2±7.8 %, 22.5±2.6 kg/m^2) who were picked with convenience sampling method among Sport Sciences Faculty students who are physically active and heathy between 18-24 ages participated in this cross-sectional method comparison research and completed whole study successfully.

Participants who were male or female and aged between 18 and 21years, who could perform lower extremity joint range of motion movements successfully, and who signed the consent form were included in the study. Before the data collection, participants were informed about the aims and the methods of the research and informed volunteer consent form was signed by all the participants. This research was carried out in accordance with the Declaration of Helsinki. The ethical approval was received from Eskişehir Technical University, Science and Engineering Sciences Medical Research and Publication Ethics Committee (Date: 30.04.2019, Protocol no: 10874).

Procedure.

Measurements were performed in the Laboratory of Human Performance in Eskişehir Technical University Sport Sciences Faculty. Blind goniometric measurements were taken by one of the two researchers (CK&BŞ) in a random order. Measurements were performed three times for each joint motion of all participants and in every measurement the other researcher who did not perform the measurement recorded the results by reading it on the screen of the smart phone or UG indicator. In every measurement these procedures were repeated. These three measurements were averaged and recorded for the analysis [13, 14].

The professional measurer has the experience of using both UG and smart phone application in the joint ROM measurement. Added to that, approximately 10 days before the research protocol testing and adaptation measurements about both UG and Level application were applied for both the researchers and the participants [10]. Test positions and procedures were the same in both measurement techniques. The measurements were taken unilaterally from participants' dominant side (2 left side and 28 right side). Participants first performed pedalling without any load for 3-4 minutes. Following that, for 2-3 minutes they did standard warm up session which include mobilization and dynamic extension movements to avoid the possibility of muscle strain in lower extremity. The joint range of motion measurement was implemented in a row as follows: plantar and dorsal flexion, knee extension, hip flexion in supine position; and knee flexion, and hip extension in prone position. All measurements were done in the same sessions. The first measurements of the participants were performed using UG and then they had a break for at least 10 minutes. The second measurements were taken using Level applications. After each measurement, the positions of the participants were repeated.

Participants' lower extremity maximal active joint range of motion was measured with a 12inch plastic standard UG which has 2 arms moving 360^0 (Baseline®, Model 12-1000, Chattanooga Group Inc, Hixson, Tennessee, USA) (Fig.1) and with Level application (IPhone 8®, IOS 13.1, Apple Inc., Cupertino, CA, USA) level application (App Store; (https://apps.apple.com/tr/app/%C3%B6l%C3%A7%C3%BCm/id1383426740?l=tr) with 1^0 sensitivity. This application is able to calculate the angle with 1^0 sensitivity between two segments with a working principle like a gravity-based digital inclinometer by using Iphone' s interior accelerometer sensor and indicate the result on the screen digitally (Fig.2).

The measurements using Iphone® were taken by holding the phone from long edges of short edges touching the participants' skin [10]. Neither goniometer nor Level application needed calibration. All the measurements were performed in the afternoons and similar time periods in November, 2019.

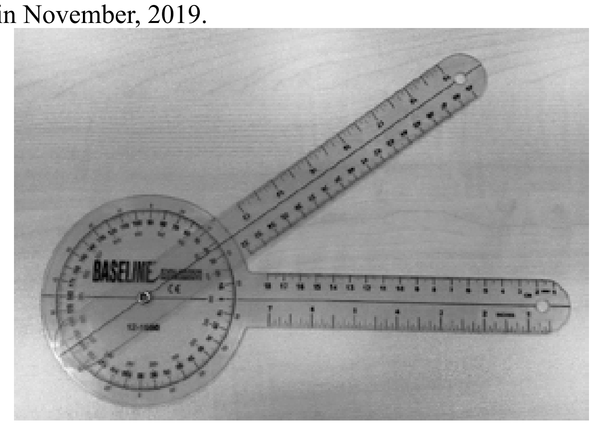

Figure 1. Universal Goniometer

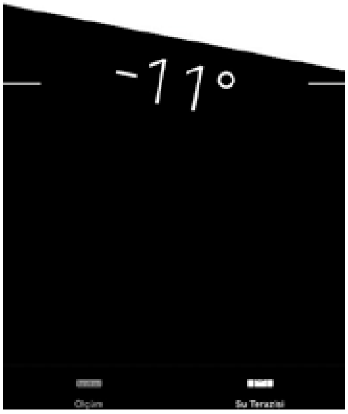

Figure 2. Iphone® Level application screen

Maximal active Plantar and Dorsal flexion joint range of motion measurements were taken while the participants were prone, bare-legged, and approximately 3-5 cm up from the ankle in the air towards the edge of the bed and the femur was supported by a towel (terminal extension). The axis of UG was placed in the axis of lateral malleolar of fibula, the stationary arm was placed parallel to longitudinal axis of fibula, and dynamic arm was placed parallel to Lateral 5. Metatarsal longitudinal axis. The participants were first asked to perform the motion of maximal active plantar flexion and the maximal degree was recorded by one of the researchers by reading from the indicator of UG. After the measurement of maximal active plantar flexion, the participants were placed in a neutral position and dorsal flexion measurement was taken in the same way [15, 16]. In the measurements taken with Level application, after the activation of the application, the long edge of the Iphone® was placed on a level with 5^{th} Metatarsal touching the heading of 5^{th} Metatarsal in the sole [9]. While the ankle is in a neutral position and the application was active, the assistant researcher touched the screen and saw the degree as 0^0. After that the participant was asked to perform maximal active plantar and dorsal flexion movements in sequence. During the measurements, the participants were reminded not to do metatarsophalangeal joint dorsal and plantar flexion. The other phases were carried out similar to the UG measurements.

Measurements of maximal active knee flexion range of motion were taken from the dominant side while the participant was lying prone, and hip and knee joints were in 0^0 flexion and feet were free. Contralateral leg was extended during the measurement [17-19].

In the UG measurements, the axis of UG was placed in lateral epicondyle of femur, the stationary arm was aligned in the midline of lateral face of femur based on greater trochanter, dynamic arm was aligned in the midline of fibula based on lateral malleolus [4, 18].

In the measurements taken using Level application, Iphone® was aligned in middle third with lateral face of fibula with lateral malleolus and the degree was zeroed. From the beginning to the end of the measurement period, the smart phone was hold stable by the researcher horizontally on the target area and this position of the joint was kept stable till the end of the motion [15, 20]. In the beginning of the motion 0^0 position was determined on the screen of the smart phone and at the end when the participant stated maximal active range of motion, the value of angle on the screen was read out and recorded by the researcher.

While measuring maximal active knee extension range of motion, the participants were lying prone when the joint of hip and knee is 0-degree flexion and feet are ease, and femur was supported by a towel (terminal extension) from dominant side. Contralateral leg is extended during the measurement [18, 19, 21, 22]. Since maximal active range of motion measurement was completed, a certain extent of hyperextension was observed in the measurement of knee extension. In the UG measurement, the axis of UG was placed in lateral epicondyle of femur, its stationary arm was on midline of femur's lateral face and aligned with greater trochanter, and the dynamic arm was placed on the midline of femur's lateral face and aligned with lateral malleolus and heading of fibula [4, 18]. In the measurements performed using Level applications, the long side of Iphone® was placed approximately 10-15 cm below tibial tuberosity in the middle third of the tibia anterior side of tibia. The other phases were performed in the knee flexion.

The measurement of maximal active hip flexion range of motion was performed as participants were recumbent and the hip joint was at 90^0 position. During the measurements, the axis of UG was aligned in the area of greater trochanter, the stationary arm and dynamic arm were aligned in the midline of lateral face of femur with lateral epicondyle. In the measurement taken with Level application, Iphone® was placed in the center of lateral face of femur with lateral malleolus.

The measurement of maximal active hip extension range of motion was applied prone and extended knee position. The participants were suggested to avoid hip abduction and pelvic tilt towards lumbar region. The axis of UG was placed on greater trochanter. The stationary arm was aligned with the body and dynamic arm was aligned with femur shaft [23]. In the measurements done with Level application, after the activation of it, Iphone® was held longitudinal on the lateral mid of femur and on the center of lateral femoral epicondyle and greater trochanter on the skin. The measurements with Iphone® were performed as mentioned before.

Statistical analysis

Data were analysed using SPSS (Version 20, IBM, Armonk, NY, USA) and NCSS (Version 2021, Kaysville, Utah, USA) analysis programs. Descriptive statistics were used for measurements obtained by UG and Level applications and this set of data was expressed as means and standard deviations. Shapiro- Wilk test was used to see whether the variances were normally distributed and no extreme values were determined in the set of data in boxplot graphics. Simultaneous validity of

Level application was tested using Pearson correlation coefficient at (r) %95 confidence interval level. As for the LoA (reliability) of the mean of UG measurements and Level application measurements, intraclass correlation coefficient (ICC) in the range of %95 reliability and Cronbach's Alpha value were calculated.

Bland-Altman graphics were used to evaluate LoA and potential systematic bias of plantar flexion, dorsal flexion, knee and hip flexion and extension ROM measurements completed with the two different measurement techniques. In Bland- Altman method, %95 confidence interval (CI; d±1.96 SD) should be close to zero and the distribution of measurement values should be in the limits of reliability as far as possible.

Results

Table 1 shows the mean values of the measurements obtained using UG and Level application. Additionally, the results of Pearson correlation coefficient analysis conducted to see relationship between the values of joint range of motion committed with UG and Level application were displayed in Table 1. The results of Pearson correlation coefficient analysis revealed a positive correlation between the values of joint range of motion obtained through UG and Level application (r^2 = 0.44-0.94, p <0.05). In hip flexion and knee extension range of motion measurements, these values were 0.19 and 0.44, respectively. Except for hip flexion and knee extension, a statistically highly significant positive correlation was found in all values of joint range of motion (p<0.001).

Table 1 shows the intraclass correlation coefficient value in %95 confidence interval of internal consistency between the measurement methods used for the LoA between the two different measurement methods. Between UG and Level applications, a high LoA was observed in almost all angles of motion (P<0.05). Cronbach's Alpha values of 0.7 or higher values have been considered important for internal consistency [24, 25]. In this line, a high level of internal consistency was found for joint range of motion values except for knee extension (0.436).

The agreement between the values of joint range of motion measured with UG and Level application was shown in Bland – Altman graphics in Figure 3. Limits of Agreement suggested by Bland and Altman is regarded as a standard to test the agreement between different methods measuring same amount [26]. The great majority of range of motion measurements shown in Bland – Altman graphics is within LoA calculated with the formula the mean difference ± [1.96x(standard deviation of differences)]. Accordingly, Bland – Altman graphics show a high agreement between UG and Level application measurements.

Discussion

Due to its accessibility and their feature of internal motion unit (IMU) (3d accelerometer, magnetometer, and gyroscope), smart phones have been started to be used extensively in scientific and clinical research for especially physical activity monitorization. Especially in joint range of motion and joint angle measurements, its usage as a goniometer is very common [27]. Smart phone sensors can be used as goniometers for statistical measurements instead of laboratory goniometers in terms of validity and reliability in clinical research [28]. As such, this research aimed to explore if there was a difference between the usage of UG and Level Application.

Wellmon et al., [29] compared smart phones operating IOS and android systems with laboratory tools and UG and found gives statistically significant results between of intraclass correlation coefficient values (ICC= 0.99–1.00). These results are similar to the results of our study (Table 1). In a study which evaluates the correlation between UG and smart phone applications measuring knee joint range of motion, using smart phones instead of goniometer was found to be reliable [30]. In the same study it was stated that smart phone applications were highly correlated with traditional laboratory tools (Pearson's correlation and interclass correlation coefficient > 0.93). In our study this value was found to be ICC =0.908; p=0.83 for knee flexion and ICC= 0.607; p=0.44 for knee extension. According to Bland- Altman plot analysis, the results were within the statistically reliable and useable limits. In Hambly et al.'s study, [20] an inexperienced person conducted knee flexion laboratory measurements using the phone

Table 1. The statistics of the hip, knee and ankle joint range of motion measurements with UG and Level application

Joint Motion	Mean Standard Deviation		Pearson correlation coefficient		Intraclass correlation coefficient between		
	Level App	UG	r^2	0.95 Confidence Intervals	ICC	Cronbach's Alpha	0.95 Confidence Intervals
Dorsiflexion	17.8±4.4	17.8±5.0	0.94**	0.946-0.988	0.983 ƚ	0.967	0.931-0.984
Plantar flexion	52.9±10.2	45.3±10.5	0.78**	0.767-0.943	0.883 ƚ	0.938	0.769-0.943
Knee flexion	129.4±5.9	126.5±6.5	0.83**	0.823-0.958	0.908 ƚ	0.952	0.817-0.955
Knee extension	1.6±0.8	2.4±0.9	0.44*	0.092-0.689	0.607 ƚ	0.436	0.096-0.685
Hip flexion	124.3±7.5	121.2±7.0	0.19**	0.795-0.951	0.896 ƚ	0.945	0.793-0.949
Hip extension	20.3±5.6	15.7±4.9	0.77**	0.758-0.941	0.878 ƚ	0.935	0.759-0.940

ƚ p<0.001, ** p<0.01, * P<0.05; UG - universal goniometers; ICC - intraclass correlation coefficient.

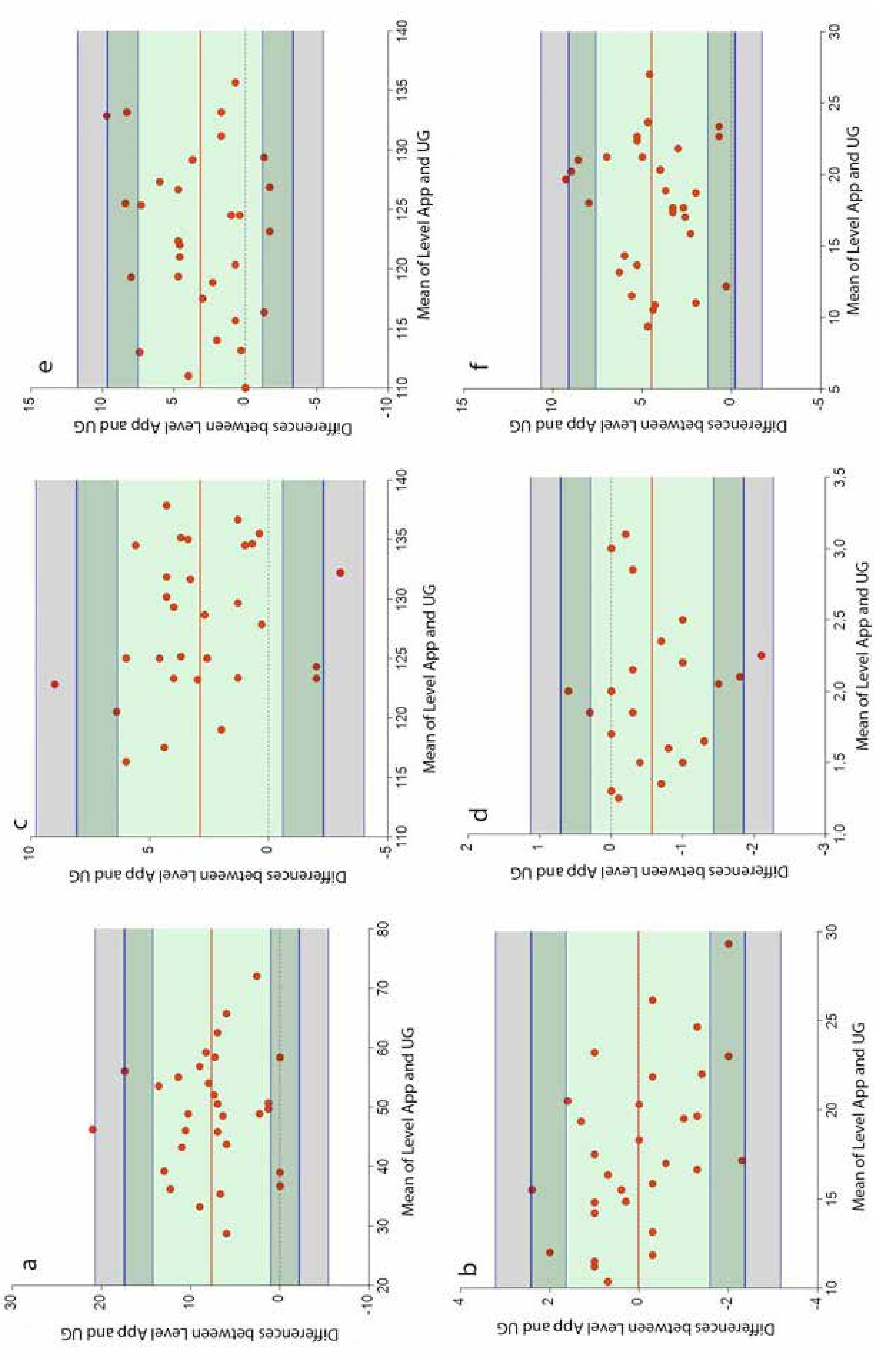

Figure 3. Bland – Altman graphics for Level App. and UG maximum active joint range of motion measurements (a) Plantar Flexion, (b) Dorsal Flexion, (c) Knee Flexion, (d) Knee Extension, (e), Hip Flexion, (f) Hip Extension. Red horizontal line remarks mean difference, blue horizontal thin line is for upper and lower confidence interval, blue horizontal thick line is for upper and lower LoA (Diff± 1.96 x SD).

and found a statistically significant correlation between laboratory goniometer and the smart phone application (r=0.932; p<0.01).

In their study which compared digital goniometer and smart phone applications in lower extremity measurements, Mohammad et al., [31] found ICC values for hip flexion, knee flexion, ankle dorsiflexion and ankle plantar flexion as 0.93, 0.93, 0.52 and 0.57, respectively. These results showed similarity with our study. Statistically significant but low level of correlations were found in hip and ankle measurements. While performing camera-based goniometers analysis several problems such as alignment of the camera to the joint or difficulty of placing the camera on smaller joints, however; these problems were not experienced with smart phone IMU sensors [32]. In another research in which ankle joint ROM was measured using IMU sensors, ICC for dorsiflexion was found to be 0.91 and ICC for plantar flexion was 0.82 [15]. In our study these values were found to be 0.98 and 0.88, respectively. Especially these values are considered higher compared to the results of studies conducted on dorsiflexion. The main reason of this can be attributed to the position during dorsiflexion or the application to be used [15, 33, 34]. In our study statistical methods were preferred to determine joint ROM and angles of joint. Camera- based applications can be used for dynamic motions. While Milani et al., [27] stated that camera- based applications might result better for dynamic motions, if the smart phone applications are updated, a new verification analysis needed to be performed by the application developer not only to affirm individually change but also to determine the capacity and the effect of this change on the whole software system.

Even though the results of the research show validity for UG and Level application, it has limitations. First, in ICC method only intra-class correlation was used. For the future studies inter-class correlation should also be added. In addition to passive motions, future research should investigate dynamic motions. Moreover, except for sagittal plane, different plane motions should be added.

Conclusion

As a conclusion statistically significant results for Dorsiflexion, Plantar flexion, knee flexion, knee extension, hip flexion and hip extension were obtained. In light of these results, Level app can be used instead of UG in clinical studies.

Highlights

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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