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ORIGINAL ARTICLE

MODIFICATIONS OF ARTHROMETRIC TEST WITH KT-1000 IN ASSESSING PATIENTS AFTER ACL INJURY

MODYFIKACJE BADANIA ARTROMETRYCZNEGO Z UŻYCIEM KT-1000 W OCENIE OSÓB Z USZKODZENIEM ACL

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ABSTRACT

Introduction

The aim of this study was to validate the reliability of the KT-1000 modified arthrometer with hand-held dynamometer in active and passive condition of the knee joint stabilization. Performing the test in active conditions may give reliable information that can be used in patient follow-up with an injuried ACL.

Materials and methods

Two groups was examined: 21 patients with diagnosed anterior cruciate ligament rupture and 16 healthy controls. The modification of the KT-1000 was done by adding a dynamometer to allow the therapist to measure the strength used in the arthrometric test. The difference in the results was also evaluated according to the measurement conditions.

Results

Intraclass correlation coefficient (ICC) was performed to examine the reliability of measurements and passive ICC values were 0.97 and ICC = 0.89 under active conditions. Significant differences in the parameters tested in passive conditions also allowed for the determination of ROC curves with reliable cut-off points for both translation and stiffness coefficient.

Discussion

Modification of the KT-1000 with hand-held dynamometer allowed to obtained data to allow for joint stiffness to be observed which could provide opportunities for monitoring the influence of different forms of therapy on the mechanism of active knee stabilization.

Conclusion

The KT-1000 hand-held dynamometer modification is a sensitive tool for diagnosing knee instability and may be an alternative device in clinical practice. Also, a change in the condition of testing sagittal knee translation in the form of active muscle stabilization results in significantly differential outcomes.

Keywords: KT-1000 arthrometer, anterior cruciate ligament, arthrometry, knee stability

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STRESZCZENIE

Wstęp

Celem badania była walidacja zmodyfikowanego artrometru KT-1000 uzupełnionego o dynamomter ręczny. Pomiar artrometryczny wykonywano w warunkach czynnej i biernej stabilizacji stawu kolanowego. Przeprowadzenie testu w warunkach aktywnych może uzupełnić informacje kliniczne, które można wykorzystać w monitorowaniu pacjentów z uszkodzonym więzadłem krzyżowym przednim podczas rehabilitacji.

Materiały i metody

Zbadano dwie grupy: 21 pacjentów ze zdiagnozowanym zerwaniem więzadła krzyżowego przedniego i 16 zdrowych osób kontrolnych. Modyfikację KT-1000 przeprowadzono poprzez dodanie dynamometru, aby umożliwić pomiar siły użytej w teście artrometrycznym. Różnicę w wynikach oceniono również w zależności od warunków pomiaru.

Wyniki

W celu zbadania niezawodności pomiarów wykonano współczynnik korelacji wewnątrzklasowej (ICC), a wartości ICC biernego wynosiły 0,97, a ICC = 0,89 w warunkach aktywnych. Istotne różnice w parametrach testowanych w warunkach biernych pozwoliły również na wyznaczenie krzywych ROC z wiarygodnymi punktami odcięcia zarówno dla współczynnika translacji, jak i sztywności.

Dyskusja

Modyfikacja KT-1000 za pomocą ręcznego dynamometru pozwoliła na uzyskanie danych umożliwiających obserwację sztywności stawów, co może dać możliwości monitorowania wpływu różnych form terapii na mechanizm aktywnej stabilizacji kolana.

Wnioski

Modyfikacja ręcznego dynamometru KT-1000 czułego narzędzia do diagnozowania niestabilności kolana i może być efektywnym urządzeniem w praktyce klinicznej. Ponadto zmiana warunków badania translacji strzałkowej kolana w przy aktywnej stabilizacji mięśniowej skutkuje istotnie zróżnicowanymi wynikami i daje informację na temat skuteczności stabilizacji mięśniowej. Dodatkowo testem ROC uzyskano wartości graniczne translacji oraz współczynnika sztywności.

Słowa kluczowe: artrometr KT-1000, więzadło krzyżowe przednie, artrometria, stabilność stawu kolanowego

Introduction

Anterior cruciate ligament (ACL) tear is one of the most common knee injuries. Acute torsion of the knee can lead to complete ACL rupture (Magnussen *et al.,* 2013, Behrens *et al.,* 2013). Arthrometry using a non-invasive arthrometer is in addition to the clinical examination of ACL function. One of the most popular and used clinically is the KT-1000 arthrometer (MedMetric, San Diego, CA, USA). The KT-1000 is as reliable as more sophisticated arthrometers (eg RSA) and advanced measuring methods such as computerized navigation systems used during ACL reconstruction (Tyler *et al.,* 1999, Monaco *et al.,* 2009, Isber *et al.,* 2006). It is a reliable tool used for examining stability in sagittal plane both before and after surgery. One of advantages is the simplicity of use and the possibility of performing it during the appointment without special adjustment of the office (Forster *et al.,* 1989, Arneja *et al.,* 2009). When measuring undamaged or ruptured ACL, the KT-1000 was more accurate than the Rolimeter which is also economical and easy to use (Balasch *et al.,* 1999, Ganko *et al.,* 2000). For the accuracy of the results obtained in the KT-1000 arthrometric test it does not matter whether the patient is anesthetized or not. However, the investigator's experience has a significant influence on accuracy of the KT-1000 results (Ballantyne *et al.,* 1995, Berry *et al.,* 1999, Sernert *et al.,* 2001). The results of the test also depend on factors such as the angle of flexion in the joint, strength used in the study, activation of the stabilizing muscles of the joint and sex of the examined person (Markolf *et al.,* 1981, Markolf *et al.,* 1984, Rangger *et al.,* 1993, Strand *et al.,* 1995, Torzilli *et al.,* 1991). Measurement in clinical practice using the KT-1000 is used in conditions of full muscle relaxation. The addition of the displacement measurement giving a quantitative result in milimeters, with the variable representing quantitative force F [N] used in the test, gives the possibility of calculating the stiffness coefficient k for deflection in response to forces acting on the elastic body $k = F/\Delta x$, where Δx is the elongation of the body, and F is a stretching force. The k value can be used to assess the stiffness of joint stabilizing tissues, which may be useful in the treatment of a patient after a traumatic injury to the mechanism of passive stabilization of the joint.

Material

The study group was consisted of 37 people (21 in G group and 16 in CG – control group). In group G there were 11 men and 10 women aged 21 to 60 years (34.2 ± 9.7), weighing 54 kg to 84 kg (68.9 ± 8.1) and body height from 159 cm to 182 cm (171.04 ± 7.6). In the CG group there were 9 men and 7 women aged 23 to 24 years (23.3 ± 0.6), body mass 54 to 84 kg (68.9 ± 9.6) and body height 158 to 183 cm (173.69 ± 8.4).

Inclusion and exclusion criteria

The study involved patients who had been either diagnosed by orthopaedist complete isolated anterior cruciate ligament rupture and full mobility in the knee joint. Exclusion criteria were damage to other anatomical structures in the knee joint which was diagnosed during clinical examination and also age below 18 years.

The CG group (control group) was comprised of active patients which did not report any knee afflictions and other injuries with joint instability in the past and in clinical examination. The research project was approved by the Bioethics Committee of the Academy of Physical Education in Katowice.

Methods

The test consisted of two parts. The first was a "classical" measurement of the forced translation of the crus in the sagittal plane at the patient's passive attitude at a knee flexion angle of 30 degrees. According to the instructions, the patient was instructed to "maximal knee relaxation". The investigator measured to the "hard endpoint".

The second measurement was the original proposal to modify this study. In an examination patient was instructed to "tighten the muscles and immobilize the knee," then the measurement was performed.

Each test was performed 3 times, and the mean values were analyzed statistically. The study was performed by one investigator – an experienced physiotherapist.

Tool

Arthrometric examination of the knee was performed with a modified device KT-1000. The modification consisted in adding to the KT-1000 the spring dynamometer for measuring tensile forces [N] denoted by the number 92/14. The dynamometer has been checked at the Department of Precision Mechanics, obtaining a certificate of verification number 133/14.

Results

In order to verify the reliability of the test tool as the modified KT-1000, the intraclass correlation coefficient (ICC) values for the displacement variable (x) and stiffness (k) were determined. The ICC values for these variables under passive and active conditions in the group G and CG are presented below.

The repeatability of the results obtained with the modified KT-1000 is in the interval of excellent scores. The Mann-Whitney U test was used to verify the significance of the difference in results according to measurement conditions and group.

The results of displacement as well as stiffness differ significantly from one another depending on the measurement conditions (Table 1, Table 2). Measurement in active conditions may give other important information in the diagnosis and treatment in anterior instability of the knee.

Comparing the results obtained in the G and CG groups of the x and k parameters a statistically significant difference was achieved which indicates that measurement in passive conditions is a differentiation study of ACL damage (Table 1, Table 2).

For the results obtained during the study under active conditions, the differences between G and CG groups are not statistically significant for any parameter (Table 4). This modification cannot differentiate classification of ACL damages. However, the results indicate a statistical tendency pointing to a higher translation and less stiffness of the knee in patients.

The ROC curves were determined to provide reliable cut-off points and to diversify ACL patients from healthy subjects and provide area under curve (AUC) values for x and k parameters under passive and active conditions (Figure 1, Figure 2). AUC is in the range of <0; 1>.

In the case of passive measurement, the results allow to set 7 mm as the cut-off point. For the k factor in passive conditions the cut-off point is 17222.22 N/m. In passive tests AUC values are very close to 1 for both x and k, which means very high power of the model (Table 5, Table 6).

In case of active conditions, the results allow to determine the 3 mm value as the cut-off point. For k in passive conditions the cut-off point is 40000 N/m.

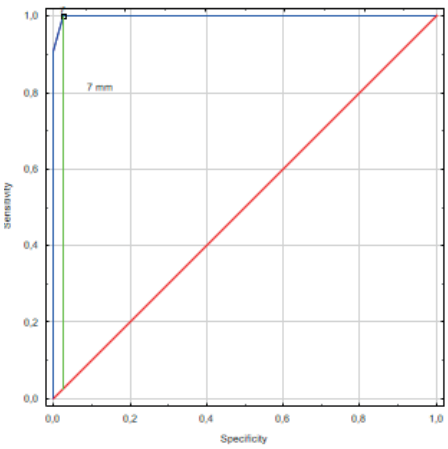

Figure 1. Area under curve (AUC) values for x and k parameters under passive conditions

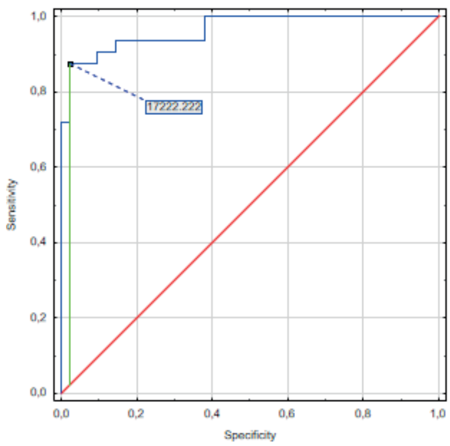

Figure 2. Area under curve (AUC) values for x and k parameters under active conditions

Table 1. ICC for translation (x).

Variable	Test Conditions	ICC	Group
x	passive	Total	0.97
		Group G	0.93
		Group CG	0.93
	active	Total	0.89
		Group G	0.89
		Group CG	0.91
	passive and active	Total	0.97

Table 2. ICC for the stiffness coefficient (k).

Variable	Test Conditions	ICC	Group
x	passive	Total	0.97
		Group G	0.93
		Group CG	0.93
	active	Total	0.89
		Group G	0.89
		Group CG	0.91
	passive and active	Total	0.97

Adopted ranges for intraclass correlation:
1. Less than 0.40 – weak
2. Between 0.40 and 0.59 – sufficient
3. Between 0.60 and 0.74 – good
4. Between 0.75 and 1.00 – excellent.

Table 3. Measurement results in active and passive conditions.

Variable	n	Averages in passive conditions	Standard deviation in passive conditions	Averages in active conditions	Standard deviation in active conditions	U	p
x [mm]	37	7.7	1.92	3.31	0.75	4.50	0.00
k [N/m]	37	17881.23	5849.69	43997.75	17293.29	32.00	0.00

Table 4. Measurements in group G and CG in passive and active conditions.

Variable	Passive (0)/ Active (1)	n CG	n important G	Averages CG	Standard deviation in CG	Averages G	Standard deviation in G	U	p
x [mm]	0	16	21	5.79	0.59	9.14	1.11	0.00	0.00
k [N/m]	0	16	21	22880.46	5192.32	14072.30	2479.27	15.00	0.00
x [mm]	1	16	21	3.04	0.79	3.51	0.67	106.50	0.058
k [N/m]	1	16	21	46010.10	34813.49	30588.89	4299.40	107.50	0.067

Table 5. AUC for translation and stiffness in passive conditions.

	for passive conditions					
	AUC	SE	AUC lower 95%	AUC upper 95%	z	p
variable (x)	0.999	0.002	0.996	1	292.345	0.0000
variable (k)	0.965	0.019	0.927	1	24.262	0.0000

Table 6. AUC for translation and stiffness in active conditions.

	for active conditions					
	AUC	**SE**	**AUC lower 95%**	**AUC upper 95%**	**z**	**p**
variable (x)	0.743	0.059	0.628	0.858	4.136	0.0000
variable (k)	0.751	0.057	0.638	0.864	4.368	0.0000

Discussion

There is no consensus on the reliability of the KT-1000 in the published literature. Wiertsema indicates low diagnostic value of the device (Witersma *et al.*, 2008). In the study 20 people participated and the measurement was performed with 89 N force by 2 investigators. Also Jardin signalizes that the results of lighter measurements using KT-1000 do not correlate with radiographic measurement using TELOS device (Jardin *et al.*, 1999). Hyder's studies show a lack of correlation between clinical trial and KT-1000 results (Hyder *et al.*, 1997). Forster demonstrated that the KT-1000 can provide reliable and statistically significant results by investigating using 67 N and 89 N by four investigators (Forster *et al.*, 1989). Our results show the excellent reliability of the KT-1000 modified instrument for both passive and active conditions. Modification of the device does not complicate the measurement process and its use in the office is as straightforward and economical as described by Ganko by comparing the KT-1000 with Rolimeter (Ganko *et al.*, 2000). Torzilli *et al.* found the best reproducibility of the results after using the maximum possible force on the KT-1000 during the test (Torzilli *et al.*, 1991). Strand results in a group of 42 patients show the highest efficacy with the use of maximal force during an arthrometric study using the KT-1000 in 37 cases of knee instability (Strand *et al.*, 1995). Also Ballantyne in a group of 22 subjects with a unilateral ACL lesion demonstrated a high ICC score of 0.88 with a maximum strength (Ballantyne *et al.*, 1995). Our study shows that measurements for tibial translation performed by one tester give ICC = 0.97 under passive conditions and 0.89 under active conditions. Performing the test in active conditions gives reliable information that can be used in patient follow-up with a ruptured ACL. Also, the introduction of the stiffness parameter into the patient observation process seems to be reasonable. The proposed measurement procedure is quick and easy and may give the opportunity to test for example the effect of exercise on the knee stability.

Conclusion

The results of the experiment show that the KT-1000 hand-held dynamometer modification is a sensitive tool for diagnosing knee instability and may be an alternative device in clinical practice. Also, a change in the condition of testing anterior translation of the tibia on the femur in the form of active muscle stabilization results in significantly differential outcomes and may be an important element in monitoring patient condition after knee injury during treatment and rehabilitation. Modification of the KT-1000 with hand-held dynamometer allowed to obtained data to allow for joint stiffness to be observed which could provide opportunities for monitoring the influence of different forms of therapy on the mechanism of active knee stabilization.

References

Arneja S., Leith J. (2009), *'Validity of the KT-1000 knee ligament arthrometer.'* J Orthop Surg (Hong Kong). Apr;17(1):77–79.

Balasch H., Schiller M., Friebel H., Hoffmann F. (1999), *'Evaluation of anterior knee joint instability with the Rolimeter. A test in comparison with manual assessment and measuring with the KT-1000 arthrometer.'* Knee Surg, Sports Traumatol, Arthrosc 7:204–208.

Ballantyne B.T., French A.K., Heimsoth S.L., Kachingwe A.F., Lee J.B., Soderberg G.L. (1995), *'Influence of examiner experience and gender on interrater reliability of KT-1000 arthrometer measurements.'* Phys Ther. Oct;75(10):898–906.

Behrens M., Mau-Moller A., Wassermann F., Bruhn S. (2013), *'Effect of fatigue on hamstring reflex responses and posterior-anterior tibial translation in men and women.'* PLOS ONE 8(2): e56988, February, Volume 8, Issue 2.

Berry J., Kramer K., Binkley J., G. Binkley A., Stratford P., Hunter S., Brown K. (1999), *'Error Estimates in Novice and Expert Raters – for the KT-1000 Arthrometer'*. Journal of Orthopaedic & Sports Physical Therapy;29(1) :49–55.

Forster I.W., Warren-Smith C.D., Tew M. (1989), *'Is the KT-1000 knee ligament arthrometer reliable?'* J Bone Joint Surg Br. Nov;71(5):843–847.

Ganko A., Engebretsen L., Ozer H. (2000), *'The Rolimeter: a new arthrometer compared with the KT-1000.'* Knee Surg, Sports Traumatol, Arthrosc 8:36–39.

Hyder N., Bollen S.R., Sefton G., Swann A.C. (1997), *'Correlation between arthrometic evaluation of knees using KT-1000 and Telos stress radiography and functional outcome following ACL reconstruction.'* The Knee;4(3):121–4.

Isberg J., Faxèn E., Brandsson S., Eriksson B.I., Kärrholm J., Karlsson J. (2006), *'KT-1000 records smaller side-to-side differences than radiostereometric analysis before and after an ACL reconstruction.'* Knee Surg Sports Traumatol Arthrosc 14: 529–535.

Jardin C., Chantelot C., Migaud H., Gougeon F., Debroucker M.J., Duquennoy A. (1999), *'Reliability of the KT-1000 arthrometer in measuring anterior laxity of the knee: comparative analysis with Telos of 48 reconstructions of the anterior cruciate ligament and intra- and interobserver reproducibility.'* Rev Chir Orthop Reparatrice Appar Mot;85(7):698–707.

Magnussen R.A., Pedroza A.D., Donaldson Ch.T., Flanigan D.C., Kaeding Ch.C. (2013), *'Time from ACL injury to reconstruction and the prevalence of additional intra-articular pathology: is patient age an important factor?'* Knee Surgery, Sports Traumatology, Arthroscopy, 21, 2029–2034.

Markolf K.L., Bargar W.L., Shoemaker S.C., Amstutz H.C. (1981), *'The Role of Joint Load in Knee Stability.'* J Bone Joint Surg Am, Apr;63(4):570–585.

Markolf K.L., Kochan A., Amstutz H.C. (1984), *'Measurement of Knee Stiffness andLaxity in Patients with Documented Absence of the Anterior Cruciate Ligament.'* J Bone Joint Surg Am. Feb;66(2):242–252.

Monaco E., Labianca L., Maestri B., De Carli A., Conteduca F., Ferretti A. (2009), *'Instrumented measurements of knee laxity: KT-1000 versus navigation.'* Knee Surg Sports Traumatol Arthrosc 17:617–621.

Rangger C., Daniel D. M., Stone M.L., Kaufman K. (1993), *'Diagnosis of an ACL disruption with KT-1000 arthrometer measurements.'* Knee Surg, Sports Traumatol, Arthroscopy 1 : 60–66.

Sernert N., Kartus J., Köhler K., Ejerhed L., Karlsson J. (2001), *'Evaluation of the reproducibility of the KT-1000 arthrometer, Scand.'* J Med Sci Sports: 11: 120–125.

Strand T., Solheim E. (1995), *'Clinical Tests Versus KT-1000 Instrumented Laxity Test in Acute AnteriorCruciate Ligament Tears.* J. Sports Med., Vol. 16, No. 1, pp. 51–53.

Torzilli P.A., Panariello R.A., Forbes, A., Santner T.J. Warren, R.F. (1991), *'Measurement reproducibility of two commercial knee test devices.'* Journal of Orthopaedic Research 9:730–737.

Tyler T.F., McHugh M.P., Gleim G.W., Nicholas S.J. (1999), *'Association of KT-1000 Measurements With Clinical Tests of Knee Stability 1 Year Following Anterior Cruciate Ligament Reconstruction.'* Journal of Orthopaedic & Sports Physical Therapy;29 (9) :540–545.

Wiertsema S.H., van Hooff H.J., Migchelsen L.A., Steultjens M.P. (2008), *'Reliability of the KT-1000 arthrometer and the Lachman test in patients with an ACL rupture.'* The Knee Mar;15(2):107–110.