Closed kinetic chain isokinetic values in football players: Pilot test

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Summary

Objectives: To determine the feasibility of an isokinetic test for lower limbs in kinetic closed-chain in football players in two moment of the season, in addition to obtaining their reference values of peak force and power output.
Design: This is a longitudinal, prospective, observational study with a descriptive phase and comparative phase and open.
Methods: 16 professional football players from second division of Mexican League between 17 and 21 years were evaluated, making a isokinetic testing for lower limbs in kinetic closed chain at 60 °/s, 10 repetitions, at the beginning and end of the season.
Results: The analysis was realized by laterality. Isokinetic reference values were obtained in this group of players for force (Nm) and power (W); the difference of peak force between both sides of the extensors chain was 5.45% initially and 9.52% at the end; for flexors was 14.30% and 9.19% at the end; for the flexor/extensor relationship was 23% initially an 24% in the final test. The progression between the beginning and the end of the season showed increased isokinetics values between measurements of non-dominant mainly muscle groups.
Conclusion: The test meets the characteristics required to perform a new test, is applicable and useful for evaluating individual performance in the biomechanics of muscle strength and power at low speed in a functional muscle chain, multiaxial and will identify imbalances, prevent injuries and even make assessments after recovery in the event of an injury.

Key words:
Dynamometry. Anaerobic power. Agility. Closed kinetic chain.

Valoración isocinética en cadena cinética cerrada en futbolistas: Prueba piloto

Resumen

Objetivo: Determinar la viabilidad de realización de una prueba isocinética en cadena cinética cerrada de miembros pélvicos en futbolistas en dos momentos de la temporada, además de obtener sus valores de referencia de fuerza pico y potencia.
Diseño: Se trata de un estudio prospectivo longitudinal observacional con una fase descriptiva y una comparativa y abierto.
Métodos: 16 jugadores profesionales de segunda división de la Liga Mexicana de fútbol de entre 17 y 21 años de edad fueron evaluados, realizando una prueba isocinética de miembros pélvicos en cadena cinética cerrada a 60°/s, 10 repeticiones, al inicio y final de la temporada.
Resultados: El análisis de hizo por dominancia. Se obtuvieron valores isocinéticos en este grupo de jugadores para fuerza (Nm) y potencia (W); la diferencia de fuerza pico entre ambos lados de la cadena extensora fue de 5,45% inicialmente y final de 9,52%; para flexores fue de 14,30% y final de 9,19%; en cuanto a la relación flexores/extensores fue de 23% inicial y 24% al final. Además, la comparación entre el inicio y final de temporada mostró incremento de los valores isocinéticos entre las mediciones de los grupos musculares no dominantes principalmente.
Conclusión: La prueba cumple con las características requeridas para la realización de un nuevo test, es aplicable y es útil para evaluar el rendimiento individual desde la biomecánica de la fuerza y potencia a baja velocidad en una cadena muscular funcional, multiaxial y que permitirá detectar desequilibrios, prevenir lesiones e incluso realizar valoraciones después de la recuperación en el caso de una lesión.

Palabras clave:
Dinamometría. Potencia anaeróbica. Agilidad. Cadena cinética cerrada.

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Introduction

Strength and power are among the capacities needed to play football[1-3]. Isokinetics is an assessment system that uses IT and robotics to obtain and process muscle capacity in quantitative data[4]; the parameters can be measured with an analytic movement in one or multiple axes[5]; and within them agonist and antagonist muscles can be assessed alternately, in concentric and eccentric direction[6]. The results are obtained in physical magnitudes, mainly in terms of strength, power and work[6]. The closed kinetic chain (CKC) is a movement that requires multi-joint efforts[6], which has been described as "functional", proprioceptive, and that requires less anterior tibia movement over the femur, reducing the demand on the anterior cruciate ligament[7]. Via isokinetic dynamometry, muscle performance can be assessed in search of bio-mechanical balance between the same muscles on both sides (what we will call "inter-side balance") and between agonists and antagonists; this balance is associated with greater sporting performance and the prevention of injuries among athletes[8,9]. Regression forms have been obtained for theoretical isokinetic strength values, but these are only for the Open Kinetic Chain (OKC)[6,10]. During dynamic movements in football, the balance between strength and elasticity between the dominant and non-dominant sides increases joint stability; the asymmetry between strength and elasticity, as well as the reciprocal balance between agonists and antagonists (especially in the lower half of the body), play an important role in sports with asymmetrical movement patterns. This is due to the fact that the dominant side is used for play whilst the non-dominant side is used as a support[11]. To get the best performance, there should be a suitable assessment for working on improving strength and muscle power, and with it the prevention of injuries through bio-mechanical alterations in the active or passive stabilisers[6].

Anaerobic power is the capacity to produce strength and speed from energy systems that are not dependent upon oxygen[12]. The result will be a reflection of the capacity to produce energy via systems such as phosphocreatine and lactic glycolysis. Although diverse measurement methods have been created, no correlation between them have been found, perhaps due to the energy production method[13].

To have an assessment of the complete capacities, there must be reference values in both the preparation and the competition period, so as to help regulate the external and internal loads for specific players, to improve their performance and to report data that suggests over-training or fatigue[14], or to have a reference point for recovery following an injury.

In this study, the aim was to establish a pilot test of functional characteristics and to obtain their peak strength and power values in order to assess the lower body and to compare modifications that may arise over time. Until now, the isokinetic regulation values have been performed on single axis movements, which is why there are no reference values for football players in a closed chain dynamometry; for this reason it is important to have new assessments that have an impact on the performance of movements similar to the motor gesture and that provide objective results in terms of physical magnitudes.

Material and method

It is a prospective, longitudinal, observational and open study, with descriptive and comparative phases, and which aimed to establish the viability of performing an isokinetic test in a closed kinetic chain of pelvic limbs in footballers at two points of the season, as well as obtaining their reference values of peak strength and power.

The inclusion criteria were: healthy male football players, in periods of preparation and competition, that agree to participate in the study and that sign an informed consent form in accordance with the Helsinki declaration and current Mexican legislation; the exclusion criteria were: presence of joint, rheumatic or cardiovascular co-morbidities and a history of joint pathology of the pelvic limbs in the past year; whilst those eliminated were: footballers that presented skeletal-muscle injuries of the pelvic limbs during the performance of the study, those that presented complications for co-morbidities during the study, and those that dropped out of the study.

The work was carried out at the University of Football and Sports Sciences, Pachuca, Hidalgo, Mexico; between January and May 2013, with an initial sample of 18 footballers from the 2nd professional division of the Pachuca Club, during the preparatory phase and at the end of the competition period; 2 players were eliminated from the study for presenting injuries during the season. The average age of the players was 19-18 years (S ±1.51), weight 72.15 kg (S ±4.73), height 178 cm (S ±4.26), 9 right-footed and 7 left-footed, established according to their ball kicking profiles.

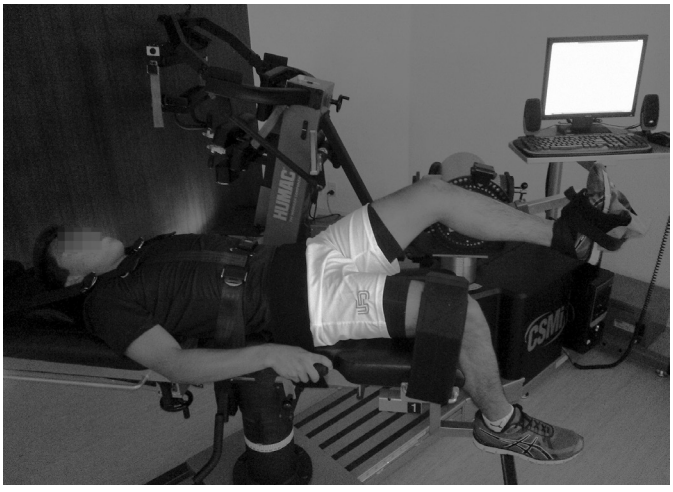
It started with a warm-up on a static exercise bike SciFit Iso 1000R, 5 min with no resistance at a rhythm of 70 revolutions per minute. Next, each player performed the isokinetic dynamometry on a CSMI Humac Norm equipment, which was adjusted in the following way:

The participant lay face up, with a starting position of a 90º hip flex, a 90º knee flex, -20º maximum knee extension, with the foot positioned in the arm rest of the dynamometer, with the foot and ankle held down with a Velcro band. Sitting: 40º rotation, 15º position forward/back, 0º horizontal backrest. Position of the dynamometer: 0º inclination, rotation 40º, height level 5. Movement of the Monorail in 28 (Figures 1 and 2).

10 repetitions were carried out at a speed of 60º/s, for both pelvic limbs starting with the right, with a continuous flexed movement - extension of the assessed limb, completing the range of movement in a concentric/concentric exercise mode. Upon completing the measurement, there had to be a co-efficient of variation in the repetitions below 10% to consider the test as valid, ensuring a minimum intraclass relationship of 0.906. Between each measurement there was a 1 minute rest. With this measurement, peak strength and isokinetic power values were obtained. At the end of the test, a cool-down was performed, just like the warm-up, and the participant also performed a series of static stretches of the quadriceps, hamstrings and triceps sural muscles for 5 minutes, with which the first assessment was considered completed.

Figure 1. Positioning for the isokinetic dynamometry.

Figure 2. Lateral view of the test.



Later, on 8th May 2013, during the end of competition (prior to the post-season), new assessments were carried out using the same procedure, thus concluding the clinical part of the study.

Results

The data analysis was carried out using the following statistical methods:

- Value average (μ).
- Standard deviation (S).
- Confidence interval at 95% (CI95%).
- Student t Test (t) for dependent samples, considering a value $p \leq 0.05$ to be statistically significant.
- The variables obtained were strength peak (Nm) and isokinetic power (W).
- The statistical analysis was carried out using the Microsoft Office Excel 2010® programme.

Values were obtained in the pre-season as well as prior to the post-season. In the parameters in which comparatively no seasonal differences were found, these values were added to establish the population to be averaged. These results are displayed in Table 1.

The ordering of the values and analyses was carried out by dominance (in the ball kick) due to the fact that there were 9 right-footed and 7 left-footed players, organising the data by "dominant" and "non-dominant". Dvir[6] reported a variation between both sides of up to 10% in strength due solely to laterality. Literature suggests that the discrepancy between both limbs should be less than 10% to be considered normal[4,6].

In this study, the difference of peak strength was discovered between both sides of the extensor hip of 5.45% (S±7.15, CI95% 3.50 $p = 0.01$), and a final value of 9.52% (S±6, 28, CI95% 3.07, $p = 0.03$) whilst for the group of flexors in the initial measurement, the percentage of difference between both sides was 14.30% (S±10.07, CI95% 4.93, $p = 0.0003$) and in the final measurement 9.19% (S±9.04, CI95% 4.43, $p = 0.02$). In terms of the existing relationship in the antagonist-agonist muscle groups (flexors/extensors), the relationship was on average 23% at the start and 24% at the end. With regards to isokinetic power, no notable difference was found in the numerical value between both sides.

Discussion

Demographic analysis

This study was carried out on young professional footballers, aged between 17 and 21 years, belonging to the same team during a tournament. Nikolaïdis[13] carried out the Wingate power test in his study, studying footballers aged between 12 and 20 years, with a very large age range considering that in this stage there are major physical changes secondary to the process of adolescence (his study objective), with some of this study group falling within the range assessed by us, however our standard deviation is not so wide (58 Nm in the dominant extensor group and 18 Nm in the non-dominant flexor group), which enables the observation that in this final stage of transition between adolescence and adulthood there is no longer a major modification. These changes were analysed by Degache *et al*[15] via the isokinetic dynamometer in OKC to 60 and 180°/s in footballers aged between 11 and 15 years, and being a smaller range, there was a major variation between those of 12 and 13 years; given this, we consider that the age range of our chosen demographic will not influence the variation of strength and power. Both authors mentioned had far greater samples than those assessed in this study.

Values obtained

The isokinetic measurements in CKC were not very widespread, despite the fact that within them no isolated muscle was found, rather

Table 1. Values obtained.

Variable	Initial values				End values			
	μ	S	CI95%	n	μ	S	CI95%	*p*
Nm ext Dom	428.56	58.14	20.14	32	***			0.09
Nm ext no Dom	389.81	67.01	32.83	16	463.75	49.40	24.20	0.0002**
Relationship between sides	5.45	7.15	3.50	16	9.52	6.28	3.07	0.01**
Nm flex dom	101	18.50	9.06	16	112.5	13.63	6.68	0.002**
Nm flex no dom	103.87	26.04	9.02	32	***			0.46
Relationship between sides	14.30	10.07	4.93	16	9.19	9.04	4.43	0.00001**
Rel ext/flex dom	24.03	4.51	1.56	32	***			0.13
Rel ext/flex no dom	23.18	3.74	1.83	16	25.87	3.30	1.61	0.02**
W ext dom	578.03	94.52	32.75	32	***			0.46
W ext no dom	586.15	102.86	35.63	32	***			0.09
W flex dom	127.81	20.76	10.17	16	153.43	30.63	15.01	0.009**
W flex no dom	131.88	26.61	13.04	16	162.06	33.49	16.41	0.003**

Nm: peak torque (strength); Rel: relation; ext: extensors; flex: flexors; dom: dominant side; no dom: non-dominant side; μ: arithmetic average; S: standard deviation; CI95%; confidence interval 95%; n: total sample; ***with no significant variation between the first and second measurements. for which the absolute value was taken as the total of measurements; **statistically significant.

the complete chain, in functional movements and with less anterior movement and patello-femoral compression. For the same reason, no bibliography can be found in different databases (Bidi - UNAM - EBSCO - MedLine, Cochrane Library) where regulatory values are established for these tests. In our literary search we found the Liebensteiner[16] reference, in which an assessment of linear CKC was carried out at a speed of 0.2 m/s, which differentiates from our measurement as its measurement units were absolute N and no Nm, our assessment was concentric and furthermore, no reference values were reported, rather simply a relationship was established in the strength between men and women.

On the other hand, it can be seen in strength that the inter-side differences between both sides coincides with the <10% described by other authors[6,17] for the extensor group (5.45±3.50%), but does not behave this way with the flexor muscles, where the discrepancy was 14.30+4.93% at the start ($p = 0.0006$), though at the end of the season the difference range diminished (9.19±4.43%, $p = 0.59$).

This coincides with the study by Rahnama *et al*[18] in which they observed a difference of >10% in the flexors between the dominant and non-dominant sides, though Lanshammar and Ribom[19] only found a difference of 8.3% for the flexors. Both authors studied groups of athletes, footballers and healthy people, but in OKC. In this latter study a difference of 5.3% was found for extensors, coinciding with our results. The study carried out by Schulz *et al*.[20] is worth a mention, as it entailed a study group of 18 footballers and a control group of 18 healthy people, aged between 16 and 36 years. Here a discrepancy of around 10% was found between both sides in the control group, a result similar to that obtained in this study, however in the group of footballers, the strength difference was of 25% in the hamstring muscles, a very large range not obtained in this or other studies analysed, which the authors put down to the effects of training, which does not coincide with that indicated by Dvir[6] or Huesa[4] as normal parameters, nor is it similar to our result (14% at the start and 9% at the end of the season, still undergoing training). Daneshjoo *et al*[11] hypothesised that the dominant side is more used for play, whilst the non-dominant side is used as support (use in CKC). In their work with 36 footballers, 97.2% had an imbalance between the dominant and non-dominant sides.

In terms of the relationship between the agonists and antagonists, our study revealed a proportion of 24±1.56% on the right side, whilst the initial left side was of 23.18±1.83 and final 25.87±1.61%. Here the peculiarity of a large difference is highlighted, when compared with the assessment in OKC, as in the reviewed studies the references already spoke of 60% of proportion[6,15] or a little less, as described by Lanshammar and Ribom[19] of 46% on the dominant side and 53% on the non-dominant. It is important to take this model into account, as it is not just a single axis movement, rather a complete muscle chain, where the strongest group of flexors is the hamstring, whilst the hip flexor and ankle extensors groups (dorsiflexors) produce less strength, whilst the extensor group, composed of extensors of the hip, the knee and ankle flexors (plantarflexors) are anti-gravity muscles, which is why the development of strength will be greater. However, it is very important to take into account that there should be a balance, both between the antagonistic muscles as well as in laterality, so as to help prevent injuries[6,11].

There are no studies in which a value of normality is determined for the flexor/extensor relationship in CKC with which to compare our result (23-25%), remaining for the time being a reference value for this age and training plan group, and as pending for comparison against another group of similar characteristics performing a different training plan, as well as considering the specific point in the season to be assessed by this parameter.

Seasonal comparison

Not all the values altered with the season. A parameter such as bilateral isokinetic power reflects that the work undertaken by the muscle fibres does not tend to change in the extensor groups. Considering that W = N x Speed, that maximum strength was used, that the speed was controlled and applying the Law of Henneman[21], it can be explained that as all the muscle fibres are used and the speed does not change, power is not notable in the change in this particular group (extensor). Anaerobic energy systems are also involved, as it is a maximum test in a short period, which determines that the co-efficient of variation of the repetitions in the test will be less than 10%: football is a low to moderate-intensity sport[2], and although anaerobic efforts are made such as repetitive sprints[1,3], they do not last long enough or intensely enough to change these variables. On the other hand, the strength of the dominant extensor and non-dominant flexor groups did not change, whilst there was a change in the dominant hip flexor. This could be explained from the bio-mechanics of the kick, which perhaps is modified during the season because of technique, not because of the strength of the ball kick. From this point of view, the dominant hip extensor will help the kick, whilst the non-dominant hip flexor will be the active stabiliser in the supporting leg; the dominant flexor group will have a quick adaptation (translated as a change of the values) as being required less, it will improve rapidly with training.

To assess the strength between both sides of the extensor muscles, a relationship was maintained below 10% as the literature mentions[4,6], however between the flexor group a difference greater than this 10% was obtained. In the strength of extensors the dominant side did not reveal statistically significant progress, whilst the non-dominant side did, perhaps therefore because the non-dominant side underwent this improvement with training due to greater adaptation, whilst that of the dominant side does not have such a rapid change as it is a side with more developed capacities. There was a seasonal variation in the relationship between both sides, though it remained below 10%. The dominant extensor-flexor relationship did not have as much statistical significance as the non-dominant extensors. The power of the extensors did not change significantly, whilst that of the flexors did, on both sides, similar to the phenomenon with the strength of the non-dominant flexor group.

This test was designed for this research, following the aspects proposed by Rodríguez[22] to assess strength:

- *Analyse the characteristics of the test in question,* as well as the strength requirements that are called upon in the search for efficiency and performance: we consider that the closed kinetic chain is functional, and that movements are required in football in which an activation of strength and power, with a point of support, are performed constantly during the changes of direction, turns, jumps, sprints, etc.
- *Select the type of main strength that has to be worked on and establish all the factors that result in the latter and that can be trainable:* likewise, with this test we will be obtaining maximum strength from the lower limbs when complete muscle chains are activated (flexion and extension) and not just isolated muscles, determining if there are deficiencies in the strength between both limbs, both hips, or muscle power, and, failing that, carry out training that aims to modify them.
- *At all times use the data provided by the corresponding assessment tests as a starting point for the design of the training programmes:* the data gathered from this research will contribute to the development of a functional technique to assess strength and power, and will therefore provide values that may be used as a reference for future assessments carried out under this procedure. In this way, we can target training towards the capacity of improving in accordance with the result and the time of the test.

  On the other hand, the key scientific criteria are also fulfilled to determine their use, proposed by the same author:

  - *Objectivity:* in this case, the examiner shall only position and guide the subject, but given that the results are obtained in physical magnitudes, they do not depend on the manipulation of the assessor.
  - *Reliability:* the results are measured with quantitative variables, approved physical units and with a high reproducibility rate[6].
  - *Validity:* with this test the strength and power were assessed reliably; and given that all the variables are controlled (lever arm, degree of movement, speed of the test, etc.) the results will always be valid as long as the procedure described is followed.

Once again, in accordance with Rodríguez[22], it should be considered which are the objectives for carrying out the test, completing the isokinetic dynamometry in closed kinetic chain with them:

- *The search for performance for a specific strength modality:* in this case the search for the production of maximum strength based on using low speed, in accordance with the Law of Hill[4,21], and counting on a complete muscle chain in agonist and antagonist direction.
- *Establish the possible tests in which the subject establishes improved performance rates and that could be the profile of sporting intervention:* with the seasonality established in the targets of this study, the test seeks to take reference from the pre-season and the end of the tournament, seeking to establish these performance rates and in the direction we wish to direct the performance.
- *Modulate the training process based on the results obtained:* given that referential parameters are established, training during the competition could be directed towards improving a capacity, which, being established by this test, is below that expected of it.

Conclusions

This work should be considered as a pilot study, however the trial proposed complies with the characteristics required to carry out a new test, with the demographic studied it is clear that it is applicable and that the assessment table presented here is useful in assessing individual performance. We consider it to be more appropriate to group the values

for laterality to dominant and non-dominant, and not just right-left, due to the variation that there could be if they were organised with a total value without considering laterality, as seen in some studies that propose normative values. The values obtained in this study act as a reference parameter in this type of players according to the age group, level of competition and sport played, subject to studying an older population or other kinds of athletes. This suggested test is useful in the bio-mechanical assessment of maximum strength muscle performance and power at low speed in a functional muscle chain, that is multi-axial and that is hugely important for different sports, as it will enable the detection of muscle imbalances that carry risk (between both sides and between agonists and antagonists), for the prevention of injuries, as a global, functional movement is performed and in a movement that reduces that anterior movement of the tibia and the tension on the anterior cruciate ligament, and even for performing assessments after recovery in the case of injury.

Study limitations

The sample was small and not random, without being representative of all players in the professional second division for which the values apply to a pilot study. Likewise, the positions of play of the participants were not taken into account, which could lead to a difference in the values as each part of the team follows specific training.

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