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# EVALUATION OF THE PHYSICAL PROPERTIES OF ATHLETES BASED ON THE RESULTS OF THE HAMSTRING McCALL TEST, CONDUCTED USING K-Deltas PLATFORM

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**Abstract:** The paper proposes a method of forming a generalized comparative assessment of the physical qualities of a group of athletes from one team based on McCall's hamstring test conducted using the K-Deltas platform. The peak loading of the legs, the rate of growth of force before reaching the peak value, the time of reaching the peak load, the rate of decrease of the load after reaching the peak value were measured. All measurements were carried out for the athlete's left and right leg, bent at the knee joint $90^0$ and $30^0$. At the same time, such physical parameters of the athlete as strength, reaction, neuromuscular fatigue were examined. These data are presented in the generalized relative ratings of athletes of the group. For a number of studies, for which high linear correlation values were obtained, regression linear relationships (as well as their largest relative deviations) are presented, that can be used in the future for preliminary estimation.

**Keywords:** McCall's hamstring test, generalized evaluation, physical data of athletes, correlation between data, recording of regression dependence.

## 1. Introduction

Very often, when analyzing various football matches, various questions arise. One of them is about the achievements which would have been possible if the sportsmen had used all their potential; another issue is the comparison of the potential of one team with the other one. Moreover, the athletes who make up the team are often referred to as "strong" or "weak", not defining the criteria of their strength or weakness. Therefore, an objective assessment outside of the football game that would allow such a determination to be made and which would give the coaches the opportunity to observe the dynamics of each athlete in the process of working with the team should be developed. This is important especially when it comes to a youth team.

The issue to be solved is to determine what indicators should be used. Let us recall that the first and only three-time world champion football player ran 100 meters in 9.9 seconds, while the world record was 9 seconds. So, one of the objective characteristics of a football player's physical condition is the strength of his legs (due to the fact that thefootball player acquires the appropriate acceleration and reaches the appropriate speed). It was measured by conducting the McCall hamstring test [1 – 5], which is used to assess the strength of isometric contraction of the muscles of the back surface of the thigh at different knee bending angles ($90^0$ and $30^0$).

Obviously, one of the important physical qualities of an athlete is his reaction. This value is estimated when measuring the rate of force growth to its peak value, as well as when measuring the time required to reach this maximum. As it was shown in [6], the rate of force development (RFD) is a measure of explosive power that reveals how quickly an athlete can develop force. An increase in this indicator can lead to an improvement in sports results. In [7,8], it was shown that elite sprinters have a higher RFD than other well-trained sprinters. In addition, muscle fatigue should be taken into account, which was obtained by calculating the rate of decline of strength after a peak load. Fatigue increases the risk of injury. As shown in [9, 10], 47% of hamstring injuries occur at the end of halves of football matches.

The football player's ability to navigate in space should also be attributed to the mental and physical capacity of a football player. In particular, Matthew Libatique, an American cinematographer who shot the biographical film ‘Pelé: Birth of a Legend’ about the famous Brazilian professional football player, carefully determined the point of the field where he set the camera. Pele hit the goal accurately regardless of the location he got into. This is a feature of outstanding football players: wherever they are on the field, and no matter how they are turned, they always know where the goal is and how to hit the ball so that it might get there. Unfortunately, the assessment of an athlete's ability to navigate is beyond the scope of this investigation, as well as the football player's ability to "see the field", the latter being a dynamic orientation in space, in contrast to the "static" orientation described above. Another important factor of a football game is team coherence, which should be mentioned here. However, all of them are not a subject of the research with the help of a physical device which is the K-Deltas platform.

With the help of the data received under McCall's hamstring test, the generalized assessment of all the studied parameters and their qualitative relative assessment was obtained. The developed technique will allow for tracing the development of athletes over time, to identify particularly strong, fast, endurance athletes. It will make it possible to single out those football players who lag behind the group and show them what parameters they should work on.

## 2. Description of the experiment.

A team of 14-year-old male football players with a body weight of 39 – 74 kg and a height of 149-184 cm was studied. Information about the dominant leg of each study participant and physical complaints of athletes was also included. All athletes were examined under the same conditions. The measurements were carried out using a digital software tool, namely, the KINVENT Deltas platform, for measuring and analyzing the force acting on a surface.

## 3. Obtained data

Fig. 1 shows the results of McCall's hamstring test obtained using the K-Deltas platform, which is given as an example. Fig. 1. contains test results issued by the platform software for one investigated athlete.


| Data | Left | Right |
|---|---|---|
| Average (kg) | 10.1 kg | 9.5 kg |
| RFD (kg/s) | 64.0 kg/s | 48.3 kg/s |
| Time to Max (s) | 4.75 | 3.08 |
| Fatigue (kg/s) | -4.30 kg/s | -1.33 kg/s |

| Data | Left | Right |
|---|---|---|
| Average (kg) | 10.1 kg | 10.1 kg |
| RFD (kg/s) | 33.1 kg/s | 64.4 kg/s |
| Time to Max (s) | 3.15 | 3.81 |
| Fatigue (kg/s) | -1.21 kg/s | -0.908 kg/s |

*Fig. 1. Results of one athlete's McCall Hamstring test obtained using the K-Deltas platform.*

Here on the left, knee flexion angles ($30^0$ and $90^0$) are given. The next column contains a bar graph showing the maximum pressure force on the platform with the left (orange) and right (blue) leg. The table in the right field contains the average pressure force with the left and right legs (first line), the rate of force increase until it reaches its maximum value (second line), the time required to reach the maximum value (third line), fatigue (the rate of force decline after reaching the maximum value).

Fig. 2. – Fig. 5 show the physical parameters obtained for 23 studied athletes. Fig. 2 a), b) illustrates peak effort; Fig. 3 a), b) shows speed of force growth until it reaches the peak load. Fig. 4 a), b) depicts the time required to reach the peak load; Fig. 5 a), b) shows the speed of force decline after reaching the peak load. In these figures, the results shown by the athlete's right leg correspond to the red broken line and are represented by red round dots; the results reached by the left leg are shown by blue squares. Figures marked with "a)" show the maximum force exerted on the platform when the knee joint is bent at $90^0$, and b) at $30^0$. The abscissa shows the numbers of the athletes according to the growth of the data for the right leg.

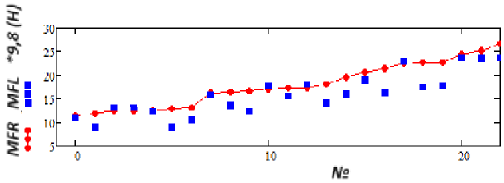


*Fig. 2.a). Peak effort developed by athletes on the platform with the knee joint bent at $90^0$*

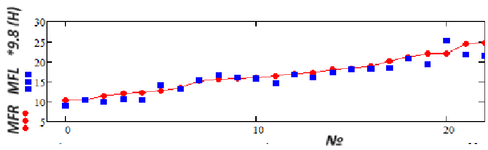


*Fig. 2.b). Peak effort developed by athletes on the platform, with the knee joint bent at $30^0$.*

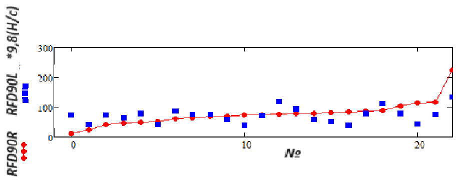


*Fig. 3.a). Speed of force development achieved by the action of the right and left legs on the platform, with the knee joint bent at $90^0$.*

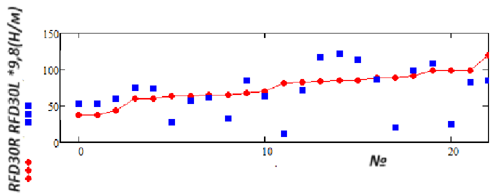


*Fig.3.b). Speed of force development achieved by the action of the right and left legs on the platform, with the knee joint bent at $30^0$.*

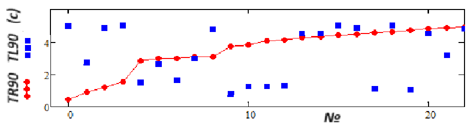


*Fig. 4.a). Time to reach the peak load with the right and left leg on the platform, with the knee joint bent at $90^0$.*

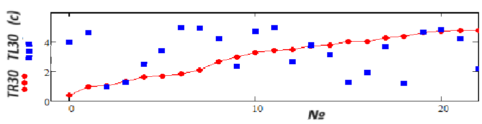


*Fig. 4. b). Time to reach the peak load with the right and left leg on the platform, with the knee joint bent at $30^0$.*

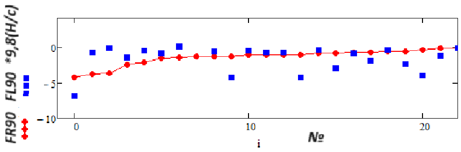


*Fig. 5.a). Speed of force decay after the peak load when the right and left legs act on the platform, with the knee joint bent at 90 $^0$..*

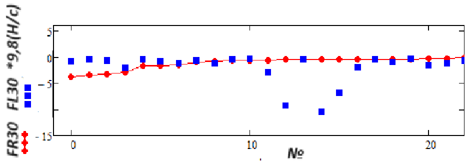


*Fig. 5.b). The speed of force decay after the peak load when the right and left legs act on the platform, with the knee joint bent at 30 $^0$.*

Table 1 shows values of linear data correlation, Table 2 contains linear regression functions of highly correlated parameters, as well as values of the largest relative deviation. Fig. 6 shows the obtained dependences (blue line) and points (red) denoting experimental data. The parameters are marked as follows: MF is peak force; RFD is speed of reaching peak effort; T is time to reach peak effort; FR is the rate of decrease of the load after the peak. The designation *R* is for the right leg, the designation *L* is for the left leg.

*Table 1*

**Linear correlation coefficients (CLC) of the studied parameters for the left and right leg, and for one leg bent at the knee joint at angles of 300 and 900**

| Parameters | CLC RL | | CLC R900 – R300 | CLC L900 – L300 |
|---|---|---|---|---|
| | 900 | 300 | | |
| MF | 0.902 | 0.942 | 0.897 | 0.913 |
| RFD | 0.475 | 0.304 | 0.435 | 0.225 |
| T | 0.141 | 0.01 | 0.163 | 0.093 |
| FR | 0.094 | 0.231 | 0.412 | 0.012 |

*Table 2*

**Linear dependence obtained for highly correlated data and the largest relative deviation**

| | | |
|---|---|---|
| *1* | *MFL30 (MFR30)* | *Y(x)* =0.495 + 0.927.*x*; *max*δ= 17% |
| *2* | *MFL90 (MFR90)* | *Y(x)* =0.284 + 0.873. *x*; *max*δ= 29.1% |
| *3* | *MFR30 (MFR90)* | *Y(x)* = 2.117 + 0.816. *x*; *max*δ= 28.7% |
| *4* | *MFL30 (MFL90)* | *Y(x)* = 2.563 + 0.844.*x*; *max*δ= 21.95% |

The resulting dependencies will allow obtaining approximate values (with an accuracy of less than 30%) of the other four parameters from one measured value. The insufficient values of the correlation coefficients for other parameters, along with the analysis of the difference in the largest relative deviation of the model and the actual (29% and 17%, Table 2) indicate that a significantly greater activation of the biceps of the thigh was observed at a smaller knee flexion angle, which also was combined with increased involvement of other key muscles of the posterior chain, including the semitendinosus, semimembranosus, and gluteus maximus.

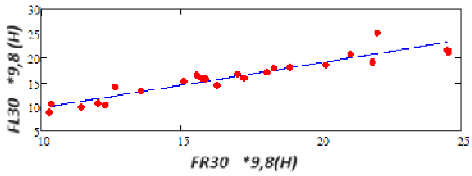


*Fig.6.a). MFL30(MFR30) (Table 2.1).*

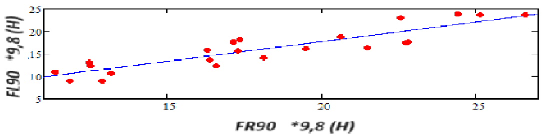


*Fig.6. b). MFL90(MFR90) (Table 2.2).*

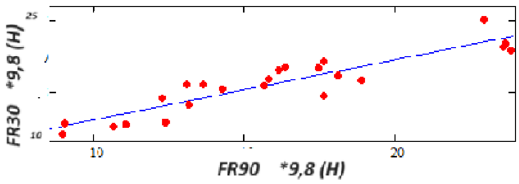


*Fig.6. c). FR30(FR90) (Table 2.3).*

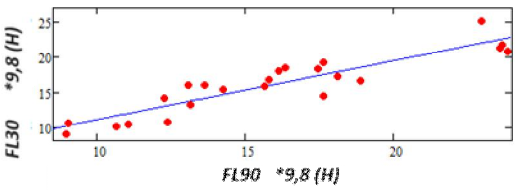


*Fig.6.d). FRL30(FRL90) (Table 2.4).*

## 4. Generalized assessment of athletes` physical qualities.

To obtain a generalized evaluation (GE) of athletes, the obtained data samples were recorded as *Xi,j*, i = 1, 2, ..., 23; *j* = 1, 2, ..., 16. Let us move on to dimensionless normalized variables:

$$x_{i,j} = \frac{X_{i,j} - min\left(X^{\langle j \rangle}\right)}{max\left(X^{\langle j \rangle} - min\left(X^{\langle j \rangle}\right)\right)}, \quad (1)$$

and the weighting factors of each component will be determined from the following equation:

$$a_j = \frac{min\left(X^{\langle j\rangle}\right)}{maxX^{\langle j\rangle}} \Bigg/ \sum_{j=1}^{16} \left\{ \frac{min\left(X^{\langle j\rangle}\right)}{maxX^{\langle j\rangle}} \right\}. \quad (2)$$

Therefore, the generalized assessment can be presented in the following form:

$$W_i = \sum_{j=1}^{16} \left\{ a_j \cdot x_{i,j} \right\}. \quad (3)$$

A qualitative relative assessment is defined as 0, if the data of the generalized assessment fall into the area of averages ± standard deviation (averages). The value becomes -1, if the data is less than or equal to the average minus standard deviations (weak, backward athletes); 1, if the data is greater than or equal to the mean plus standard deviations (strong, outstanding athletes). Table 3 contains the summary scores for all parameters, as well as the qualitative relative score for all parameters. Table 4 contains the summary score and the corresponding qualitative relative score.

*Table 3*

**Results of testing athletes in all parameters, generalized evaluation (GE) and relative qualitative assessment (RGA) of physical properties of athletes**

| Item No | GE MF score (0.446 ± 0.227) | **RGA MF** | GE RFD (0.372 ± 0.237) | **RGA RFD** | GE FR (0.74 ± 0.128 | **RGA FR** | GE T (0.201 ± 0.059) | **RGA T** |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 0.384 | 0 | 0.717 | 1 | 0.892 | 1 | 0.141 | -1 |
| 2 | 0.835 | 1 | 0.966 | 1 | 0.589 | -1 | 0.252 | 0 |
| 3 | 0.431 | 0 | 0.413 | 0 | 0.847 | 0 | 0.162 | 0 |
| 4 | 0.091 | -1 | 0.383 | 0 | 0.671 | 0 | 0.245 | 0 |
| 5 | 0.512 | 0 | 0.586 | 0 | 0.841 | 0 | 0.088 | -1 |
| 6 | 0.261 | 0 | 0.511 | 0 | 0.924 | 1 | 0.169 | 0 |
| 7 | 0.033 | -1 | 0.359 | 0 | 0.877 | 1 | 0.219 | 0 |
| 8 | 0.096 | -1 | 0.371 | 0 | 0.681 | 0 | 0.221 | 0 |
| 9 | 0.207 | 0 | 0.263 | 0 | 0.792 | 0 | 0.223 | 0 |
| 10 | 0.411 | 0 | 0.209 | 0 | 0.543 | -1 | 0.199 | 0 |
| 11 | 0.533 | 0 | 0.401 | 0 | 0.62 | 0 | 0.19 | 0 |
| 12 | 0.027 | -1 | 0.054 | -1 | 0.771 | 0 | 0.263 | 1 |
| 13 | 0.313 | 0 | 0.236 | 0 | 0.72 | 0 | 0.164 | 0 |
| 14 | 0.627 | 0 | 0.45 | 0 | 0.748 | 0 | 0.154 | 0 |
| 15 | 0.917 | 1 | 0.166 | 0 | 0.789 | 0 | 0.178 | 0 |
| 16 | 0.7 | 0 | 0.448 | 0 | 0.938 | 1 | 0.112 | -1 |
| 17 | 0.528 | 0 | 0.075 | -1 | 0.551 | -1 | 0.315 | 1 |
| 18 | 0.431 | 0 | 0.038 | -1 | 0.574 | -1 | 0.19 | 0 |
| 19 | 0.132 | -1 | 0.39 | 0 | 0.862 | 0 | 0.175 | 0 |
| 20 | 0.866 | 1 | 0.242 | 0 | 0.772 | 0 | 0.284 | 1 |
| 21 | 0.615 | 0 | 0.026 | -1 | 0.608 | -1 | 0.236 | 0 |
| 22 | 0.949 | 1 | 0.436 | 0 | 0.556 | -1 | 0.307 | 1 |
| 23 | 0.363 | 0 | 0.823 | 1 | 0.863 | 0 | 0.135 | -1 |

Table 5 contains the numbers and values of the best and worst results for each test.

The analysis of the obtained results showed that power quality was best revealed by sportsman number 22. Athletes number 2, 15, 20, 22 showed exceptionally good strength results. Athletes with numbers 4, 7, 8, 12, 19 turned out to be weak, among which sportsman numver 12 showed the worst data.

The best **reaction** proved to belong to athlete number 2. Athletes with numbers 1, 2, 23 turned out to be fast. Those with numbers 12, 17, 18, 21 are slow, among whom the athlete with number 21 lags behind.

**Muscle fatigue** turned out to be the smallest in athletes 1, 6, 7, 16, of which 16 showed the least fatigue. Athletes with numbers 2, 10, 17, 18, 21, 22 turned out to be capable of the poorest endurance, among which athlete number 10 requires special attention.

**Time of developing the maximum effort.** The best results were shown by athletes with numbers 12, 17, 20, 22, among which athlete 17 was the best. Poor results were shown by 1st, 5th, 16th, 23rd sportsman. The worst result was obtained by the 5th athlete.

As a result**,** when evaluating the data of all 16 parameters, the best results were shown by the 1st, 2nd and 23rd athletes, among which the best data was shown by the 2nd sportsman. The 12th, 18th, and 21st athletes showed poor results, among which the 12th was the worst.

*Table 4*

**Final generalized evaluation (FGE) and the corresponding relative qualitative evaluation (RQE) of the physical properties of athletes**

| *No* | **FGE** (0.399 ± 0.193) | **RQE** | *No* | **FGE** (0.399 ± 0.193) | **RQE** | *No* | **FGE** (0.399 ± 0.193) | **RQE** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.626 | 1 | 9 | 0.254 | 0 | 17 | 0.208 | 0 |
| 2 | 0.921 | 1 | 10 | 0.27 | 0 | 18 | 0.157 | -1 |
| 3 | 0.427 | 0 | 11 | 0.441 | 0 | 19 | 0.324 | 0 |
| 4 | 0.302 | 0 | 12 | 0.056 | -1 | 20 | 0.427 | 0 |
| 5 | 0.572 | 0 | 13 | 0.265 | 0 | 21 | 0.201 | -1 |
| 6 | 0.448 | 0 | 14 | 0.506 | 0 | 22 | 0.58 | 0 |
| 7 | 0.274 | 0 | 15 | 0.39 | 0 | 23 | 0.694 | 1 |
| 8 | 0.296 | 0 | 16 | 0.53 | 0 | | | |

*Table 5*

**The best and worst results and numbers of athletes**

| | Parameter | Best/No | Worst/No |
|---|---|---|---|
| 1 | F | 0.949 / 22 | 0.027 / 12 |
| 2 | FRD | 0.966 / 2 | 0.026 / 21 |
| 3 | FR | 0.938 / 16 | 0.543 / 10 |
| 4 | T | 0.315 / 17 | 0.088 / 5 |
| 5 | Final | 0.921 / 2 | 0.056 / 12 |

**5. Conclusions**

Thus, in the work, a generalized assessment of the physical data of athletes in the team was conducted. The carried out work makes it possible to:

- identify objectively the physical properties of each athlete;
- show each athlete, in particular, his strengths and weaknesses, in order to work specifically on eliminating mistakes;
- identify athletes who are worthy of the award and who should be considered for their stay in the team.

A similar test conducted after a certain period of time will show the dynamics of the development of each athlete in particular, and the team as a whole.

The resulting equations for linear regression (Table 2, Fig. 6) will allow one measured parameter to estimate the possible numerical values of others.

The insufficient values of the correlation coefficients for other parameters, together with the analysis of the difference between the largest relative deviation of the model and the actual one (29% and 17%, Table 2), indicate that a significantly greater activation of the biceps of the thigh was observed at a smaller knee flexion angle, which also was combined with increased involvement of other key muscles of the posterior chain, including the semitendinosus, semimembranosus, and gluteus maximus.

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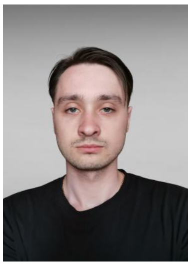
## ОЦІНКА ФІЗИЧНИХ ВЛАСТИВОСТЕЙ СПОРТСМЕНІВ ЗА РЕЗУЛЬТАТАМИ ХАМСТРИНГ ТЕСТУ МАККОЛЛА, ПРОВЕДЕНОГО ЗА ДОПОМОГОЮ ПЛАТФОРМИ K-Deltas

**Ярослав Медвідь, Корнелія Товстюк, Яна Троцька**


В роботі пропонується методика утворення узагальненої порівняльної оцінки фізичних якостей групи спортсменів з однієї команди на базі хамстринг тесту МакКолла, проведеного за допомогою платформи K-Deltas. Ми вимірювали пікове навантаження ніг, швидкість зростання сили до досягнення пікового значення, час досягнення пікового навантаження, швидкість спадання навантаження після досягнення пікового значення. Всі виміри проводили для лівої і правої ноги спортсмена, зігнутої в колінному суглобі до $90^0$ і до$30\ ^0$. При цьому досліджуємо такі фізичні параметри спортсмена, як: силу, реакцію, нервово-м’язову втому. Ці дані ми подаємо в узагальнених відносних оцінках спортсменів групи. Для низки досліджень, для яких ми отримали високі значення лінійної та середні значення лінійної кореляції, ми наводимо регресійні лінійні залежності ( також їх найбільші відносні відхилення), які можна використовувати в майбутньому для попередньої оцінки.



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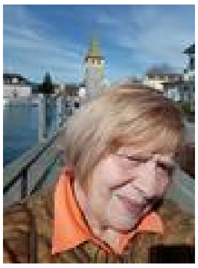
**Scientific interests**: mathematical modeling in biological systems; biomechanical measurements



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