310. Measurement of sportsman‘s jump psychomotoric reaction

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Abstract. For representatives of sport games are very important components of physical abilities – spring and rate of psychomotoric reaction. For the following sportsman's especially important is the rate of psychomotoric reaction, which defines reaction to the constantly changing ambience, similar to the sport action. Testing system, which simulates the situation of sports game, was created in the department of Informatics and biomechanics of LKKA. This system allows estimating the physical capabilities of player – spring and the speed of psychomotoric reaction. The speed of psychomotoric reaction is evaluated by making the jump-up. The influence of the height of jump-up on the spring and speed of reaction of sportsman is investigated. Considering the results of experiments and statistical analysis some recommendations are given and conclusions withdrawn.

Keywords: Jump, Psychomotoric reaction, Sportsman's jump.

Introduction

For the representatives of sport games (basketball, handball, football etc.) the following components of their physical ability are very important: spring and the rate of psychometric reaction [4, 5]. Most often the reaction time of simple reaction and the height of high-jump by using contact platform? are investigated separately. Nevertheless for representatives of the mentioned sports psychomotoric reaction rate is of particular importance as it characterizes reaction to continuously changing surrounding which is close to game activity. During the match a player has to choose only one irritant from several and to respond properly. Thus it is necessary to evaluate not only the latent reaction time but also both the situation perception time and time for performing the movement. Meanwhile the analysis of psychomotoric reaction (PMR) usually involves only the registration of time parameters not paying attention to kinematic and dynamic characteristics of motion [7]. But while analyzing separate components of psychomotoric reaction it is important to know structure of the motion. A test system for modeling of the game situations and evaluation of the physical abilities of players was developed at the department of Informatics and biomechanics of LKKA (Lithuanian Academy of Physical Education) [1,2]. The system includes dynamometric set MA-1, 6 torches around the force platform arranged in arc above the people's height, the unit generating light signals, hardware and software for their control and for the analysis of the registered information. Sportsmen under investigation have to switch of the torches lighted randomly by control system by touching them (he must jump up to reach the torches). The rate of psychomotor reaction is evaluated by the time passing from the switching on to the switching of the torch. Thus the time of psychomotoric reaction in high jump depends on sportsman's spring and the speed of simple reaction as well. During the jump the curve of ground reaction is recorded (dynamometric graph) and the time for switching of the torch is measured. But here a problem appears – in what height torches should be set in order to reflect suitably sportsman's spring and his reaction rate.

Biomechanical characteristic of rapidity

Rapidity properties are characterized by human ability to perform certain movement in minimal time. Here the short period of time at which fatigue tiredness does not appear is meant. There are distinguished three components of rapidity:

- Reaction time;
- The speed of a single movement;
- The speed of body movement (in cyclic movements) which depends on movement frequency and the cycle length.

Correlation between these indicators is small: a human may be of a very rapid reaction and simultaneously may perform slow movements. So, all the three components of rapidity are independent on each other.

In order for a human body or its parts to gain certain speed a force should act. Muscle contraction speed depends on the proportion of types of muscle fibers and on the resistance force. That's why the rapidity features are in common relation with force features.

Biomechanics of reaction

Simple and psychomotoric reactions are distinguished. Simple reaction is the response to the signal known in advance by the movement also known in advance. Simple reaction mainly is determined by a mioreflexometer when sound or light signals are generated in the place defined in advance and the person under investigation has to press a button as soon as possible after the signal appears. The time period from the origin of the signal to its interruption is the speed of simple reaction. The time of simple reaction approximately equals 200 ms.

When it is not defined in advance when and where the signal will appear and what kind of movement is to be performed – such reaction is called psychomotoric. In this case the person has to evaluate the situation, choose movement type and perform it. Investigating PMR by biomechanical means includes the following phases:

- Latent PMR time – the time from the signal start to the beginning of movement;
- Movement time – the time from the beginning of movement to its finish.

Latent PMR time is greater than the time of simple reaction as the time for situation evaluation is necessary. Latent PMR time approximately equals 300 – 400 ms. It depends on the task complexity, physical and psychical condition of person and inborn features as well.

On time axis the components (phases) of psychomotoric reaction are presented in Fig. 1.

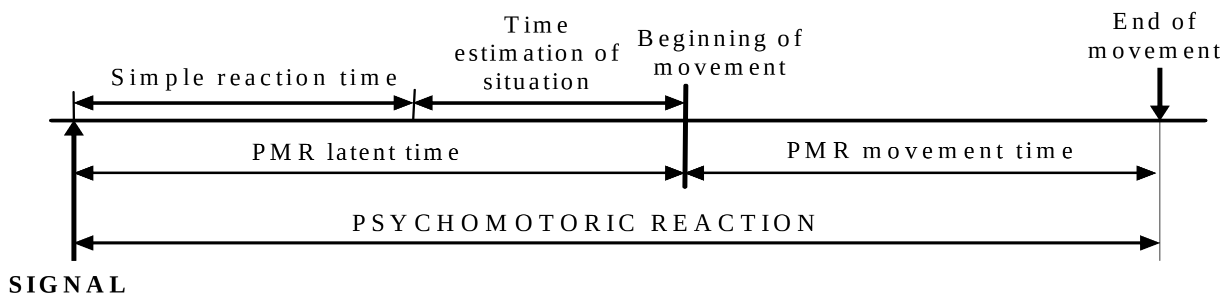

Fig. 1. The components of psychomotoric reaction

Reaction physiology. As we know not all humans have the same reaction rate to different irritants. In order to find out in what way and by what parts an organism reacts to irritants it's worth to remember reflex theory developed by Russian scientists Sechenov and Pavlov. Certain physiological mechanisms are involved into the action of each element and this action lasts certain period of time. Total reaction time depends on the formation of nervous impulse, its propagation, irritation of effector and response times. Besides nervous impulse coding and task reception rate has great influence on reaction rate. Let's analyze how these elements differ for different people. First of all irritability level of a receptor can be not the same – it depends on the resistance of receptor's membrane (the higher is the resistance the more irritant is the receptor). Even the receptors (vision, hearing, proprireceptors, etc.) of the same human can be of different irritability. The case can be met when a persons reacts better to light irritants but worse to sound and vice versa. The propagation rate of nervous impulse in neuron's axons can differ also – this parameter depends highly on axon's thickness (the thicker is the axon the higher is rate of nervous signal (information) propagation). After access to head brain at first the signal is to be evaluated at the highest possible speed and with the greatest possible objectivity (the signal has to be recoded). The more complicated is the nervous command the more time is necessary to recognize information and to make a decision. After decision is made the motion programme is to be generated (new code of nervous impulses) and at shortest time transmitted to periphery (effector). The bigger is motoneuron the bigger is its axon and higher speed of transmission of nervous impulses from spinal cord to RS. This is not the end of impulse path – it should be transmitted at the highest possible speed from RS membrane to myofibril. Transmission mechanisms of electric impulse inside RS are described in the teaching aid of Skurvydas and Co [XX]. As more high-speed RS and MV dominate in skeleton muscles, the higher is speed of transmission of nervous impulse from spinal cord to RS and from RS membrane to myofibril. The period of time from electric impulse excitation in the membrane to RS contraction force initiation is called latent muscle period. In a single RS this period can last only a few ms but when in a certain movement participate a number of not simultaneously activated RS the period can last several tenths of ms. The more high speed RS contain muscle, the shorter is latent muscle period.

As it was already mentioned different elements of reaction have specific physiological mechanisms. It appears rather often that a sportsman has comparatively high reaction rate to a simple irritant but for more complicated situations the rate is low. A sportsman in whose muscles dominate high-speed RS should not necessarily be distinguished

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by the features of high-speed transmission of electric impulse from the membrane to myofibrils, fast decision making and movement program generation. Keeping this fact in mind the results of simple reaction rate should be interpreted more carefully for the sportsmen of such branches where reacting to very complicated irritants set is necessary (e.g. players, wrestlers, etc.). The more complicated is the irritant to which the sportsman should react the longer is reaction period (mainly due to information decoding, and program generation rate). And the higher is the number of irritants the lower is reaction rate. It is determined that the reaction rate to the command STOP is higher than the one to command STANDSTILL. The reaction rate depends as well on the fact whether the irritant is known (the rate is higher if the irritant is known or expected). If the irritant is complicated but known enough the reaction rate will be relatively high, because there is no necessity to generate a new movement program before its start. For the generation of rather complicated movement program about 200 ms are wasted when for its processing only 50 ms. If a sportsman knows in advance the direction of the future movement the reaction time can be reduced twice. It is supposed that reaction rate strongly depends on movement programs data base which is accumulated during exercising. If a great number of such programs is accumulated there is no necessity to generate new ones when complicated situation appears, what reduces significantly the reaction duration.

It is important for a sportsman not only to react as soon as possible to a certain irritant but to make the necessary movement as well. Rushed movement program can reduce the final effect of movement. It is known that the reaction rate during the attempt to react as soon as possible and to follow triangular form movements is higher than following sinusoidal motions.

Experimental research

Parameters of 12 second year students of LKKA non active in sports were researched. Height of the students varied in the range 174 – 190 cm, weight in the range 38 – 96 kg.

The following parameters were registered:

- Simple reaction rate;
- Psychomotoric reaction rate and its components when the torches are at eye level;
- The same when torches are 10 cm above lifted hands;
- The same when torches are 20 cm above lifted hands.

Simple reaction was measured by mioreflexometer, psychomotoric reaction – by PMR testing system developed at the department of biomechanics of LKKA. In the last case students under investigation had to switch of a torch as soon as possible by touching it by fingers (Fig. 2).

Torch position height is adjustable. For each student the torch height was adjusted individually 10 or 20 cm above his finger tips of the lifted hands. The sequence of

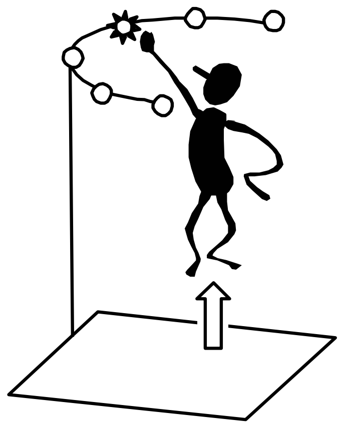

Fig. 2. Scheme of registering of psychomotorical reaction

the torches switching on was random. When a torch is switched off the next torch is switched on in 2 – 5 seconds. During the test all persons under investigation made 10 tries each. In order to switch off the torch it was necessary to jump up. During jumping up process the curve of ground reaction (dynamogram) and the time of torch switching of (psychomotoric reaction time) were registered (fig. 3).

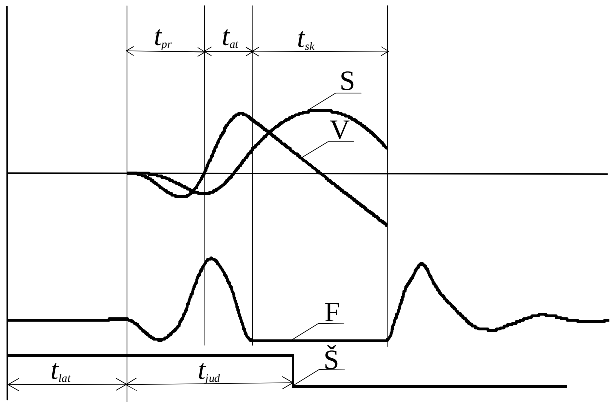

Fig. 3. Dynamogram (F), BMC of the body, velocity (v), displacement (s) and light signal (Š) registered during psychomotorical reaction research. Light signal is interrupted when the torch is touched by hand. t_{pr}, t_{at}, t_{sk} are the times of knee-bending, take-off and flight phases accordingly, t_{lat} ir t_{jud} are the PMR latent and movement times accordingly

For data processing specialized software the window of which is shown in Fig. 4 was used (except for the case of torches arranged at eye level when other software was used). Differently as in the case of investigation of complex psychomotoric reaction, in this case jump is not performed so the signal generated by the body movement is very weak and additional signal acquisition is necessary in order to determine movement start point. The registered movement signal and its recognition instant are indicated in the program window and can be corrected (Fig. 5).

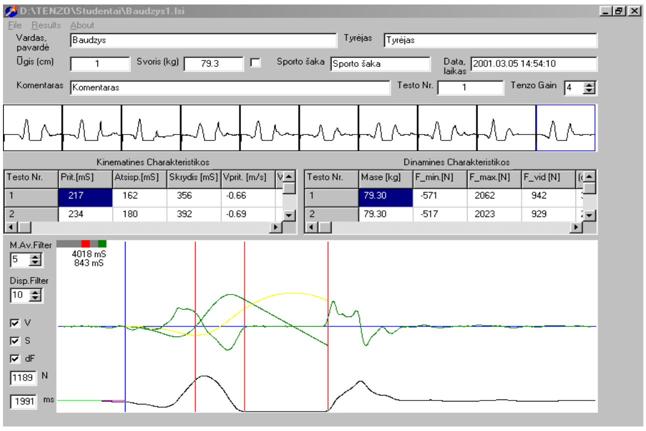

Fig. 4. Window of jump-up psychomotoric reaction parameter registration software

The parameters registered during psychomotorical reaction research are listed in table 1.

For processing the investigation results the methods of mathematical statistics and electronic spreadsheet MICROSOFT EXCEL–2000 were used. The following statistical parameters were determined: arithmetical mean, standard deviation, student's criteria *t* for reliability evaluation.

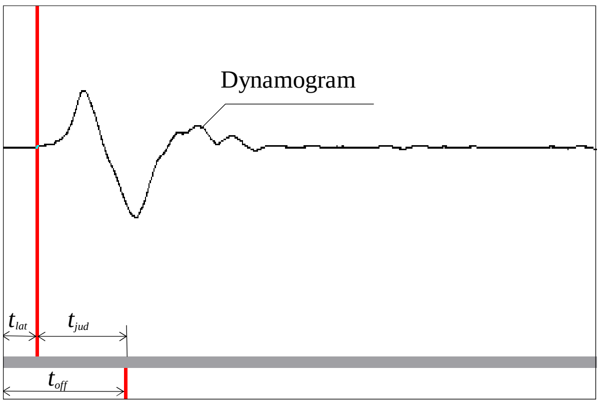

Fig. 5. Registration of psychomotoric reaction with no jump-up

Table 1. Description of kinematical and dynamical parameters of reaction and jump-up

Parameter	Parameter description
t_{pr}	*Kneel-bending phase* starts when force curve drops down from weight line and ends when the velocity changes from negative to positive
t_{at}	*Take-off phase* starts after kneel bending phase end and stops at the contact loss with the support instant
t_{sk}	*Flight phase* starts after body loses contact with the platform and stops at the body impact to the platform instant
v_{at}	*BMC speed* at the moment of losing the contact with the platform instant
s_{pr}	*Kneel-bending depth* is the maximal BMC lowering down at kneel-bending phase
h	*Jump-up height* is calculated from BMC take-off from the platform velocity ($h = V^2_{at}/2g$, where g – acceleration of gravity).
t_s	*Simple reaction time*
t_{off}	*Total reaction time* is the time period from signal appearance to the torch switch of instant
t_{lat}	*Latent reaction time* is the time period from light signal appearance to kneel-bending phase start
t_{jud}	*Movement time* ($t_{jud} = t_{off} - t_{lat}$).
m	*Body mass*
F_{maks}	*Maximal take-off force*
F_{vid}	*Mean take-off force* is calculated as the ratio of force impulse and the duration of take-off phase
$(dF/dt)_{maks}$	*Absolute dynamical force* is the maximal value of force derivative according time
R	*Relative dynamical force* (reactivity coefficient). $R = (dF/dt)_{maks}/mg$
A	*Work done* in jump-up process. Calculated as potential energy change between highest and lowest BMC positions of the body
P	*Jump-up power*. $P = A/t_{at}$
P_{sant}	*Relative jump-up power*. $P_{sant} = P/m$

Experimental results

The time of simple reaction to light signal irritator for persons under investigation was 200±63 ms, PMR latent time depended on motoric task complexity. When the torches were at eye level t_{lat} was 269±91 ms, when torches are 10 cm above finger tips of the lifted hands – 354±166 ms, when 20 cm – 345±167 ms (Fig.6.).

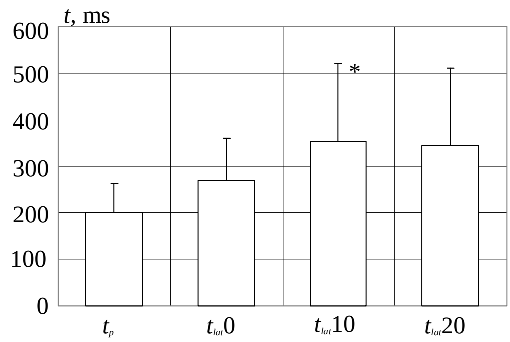

Fig. 6. Dependence of simple reaction time (t_p) and PMR latent time on jump-up height: $t_{lat}0$ – when torches are at eye level $t_{lat}10$ – when torches are 10 cm above finger tips of the lifted hands; $t_{lat}20$ – when torches are 20 cm above finger tips of the lifted hands

Difference between PMR latent time and simple reaction time is the time for situation evaluation which in case of torches placed at eye level was 71±46 ms, when torches are 10 cm above finger tips of the lifted hands – 156±108 ms, when 20 cm– 153±110 ms (Fig.7.). PMR movement time for torches at eye level was 320±60 ms, when torches are 10 cm above finger tips of the lifted hands – 491±67 ms, when 20 cm– 554±49 ms (Fig.7.). So in case of elevated torches, when it is necessary to jump-up in order to switch them off, the time for evaluation of situation and execution of movement is surely higher (p<0,05) than in case when the torches are at eye level, but it does not depend on jump –up time.

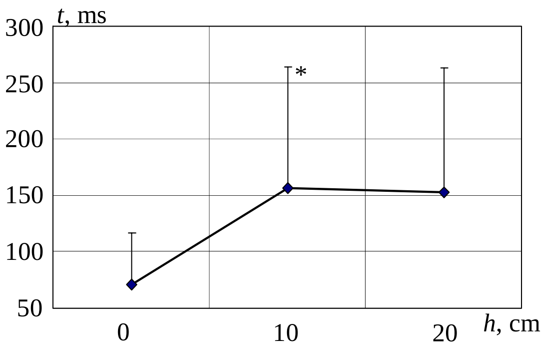

Fig. 7. Dependence of time for PMR evaluation on jump-up height. Asterisk marks statistically reliable difference (p<0,05) in comparison with PMR latent time in case of torches at eye level

Psychomotoric reaction time grows with the increment of hardness of the movement task (Fig.8.). This is obvious because for higher jump-up more time is to be spent.

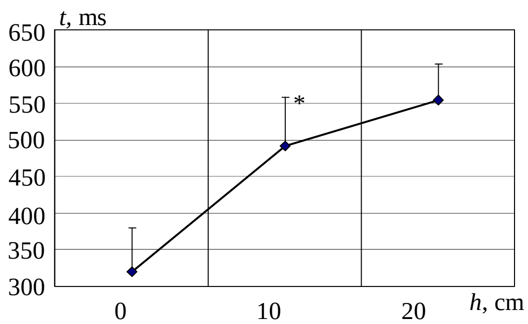

Fig. 8. Dependence of PMR movement time on jump-up height. Asterisk marks statistically reliable difference (p<0,05) in comparison with PMR latent time in case of torches at eye level

Jump-up parameter PMR and its components values for different height jumps-up are presented in table 2. It can be observed that all the parameters making different height jumps-up are surely different except latent reaction time. Jump-up parameter differences are related to the fact that for higher jump-up higher force and power are to be developed.

To find out the influence of jump-up parameters on PMR and its components the correlation coefficients between jump-up indicators and PMR were calculated. Making 10 cm jumps-up correlation between the investigated indicators is weak. But making 20 cm jump-up strong positive dependence between t_{mov} and knee-bending phase duration is observed (Fig.9.) as well as negative dependence between t_{mov} and relative dynamic force (Fig.10.). Other jump-up parameters correlate weakly with PMR parameters (table 3). Weak correlation between PMR movement time and relative jump-up power is shown in Fig.11.

Table 2. Jump-up parameters PMR and its component values making 10 cm and 20 cm height jumps-up

Parameter	Jump-up height		p
	10 cm	20 cm	
t_{pr}, ms	214±56,5	237±50,2	<0,001
t_{at}, ms	176±35,1	161±15,0	<0,001
h, cm	10,8±0,06	19,4±0,05	<0,001
t_{pmrv}, ms	845±196	919±190	<0,05
t_{lat}, ms	354±167	345±168	>0,5
t_{jud}, ms	491±81,3	574±66,3	<0,001
F_{maks}, N	1809±638	2203±447	<0,001
F_{vid}, N	674±301	962±216	<0,001
F'_{maks} , kN/s	31,7±15,6	37,3±13,4	<0,01
R, s^{-1}	40,7±19,8	48,4±17,0	<0,01
A, J	247±85,7	346±78,2	<0,001
P, W	1482±620	2157±501	<0,001
P_{sant}, W/kg	18,5±7,0	27,3±5,0	<0,001

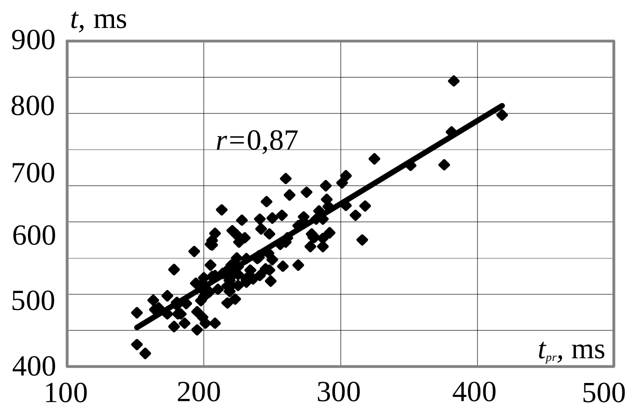

Fig. 9. Correlation between PMR movement time and duration of knee-bending phase in jump-up

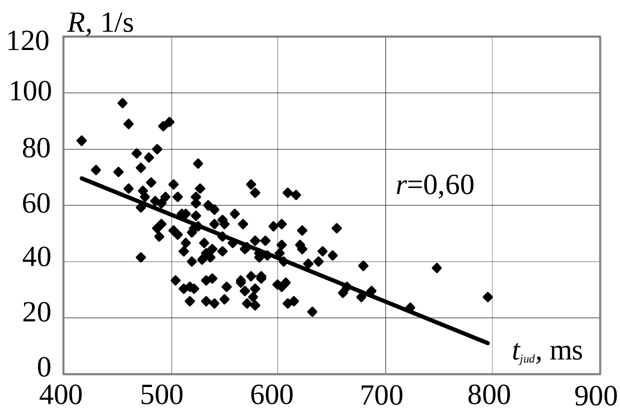

Fig. 10. Correlation between PMR movement time and relative dynamical force

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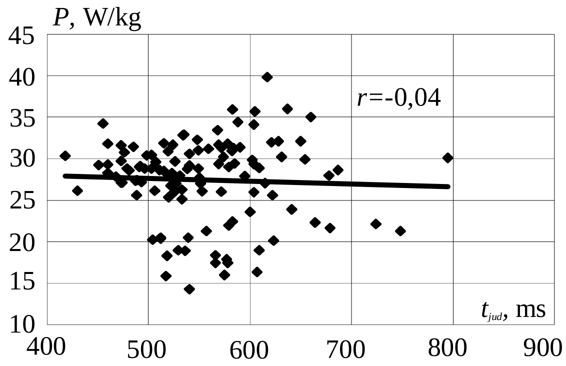

Fig. 11. Correlation between PMR movement time and relative jump-up power

Table 3. Coefficients of correlation between PMR components and jump-up parameters

	t_{pmrv}	t_{lat}	t_{jud}
t_{pr}	0,37±0,089	0,07±0,095	0,87±0,047
t_{at}	0,21±0,093	0,05±0,095	0,48±0,084
h	0,24±0,093	0,22±0,093	0,12±0,095
F_{maks}	0,00±0,095	0,05±0,095	-0,12±0,095
F_{vid}	0,14±0,094	0,13±0,095	0,06±0,095
F'_{maks}	-0,21±0,093	-0,06±0,095	-0,46±0,085
R	-0,30±0,091	-0,10±0,095	-0,60±0,076
A	0,34±0,090	0,24±0,093	0,36±0,089
P	0,23±0,093	0,20±0,093	0,15±0,094
P_{sant}	0,16±0,094	0,19±0,094	-0,04±0,095

Discussion

Psychomotoric reaction time consists of the following components:

- Sensor or simple reaction time;
- Situation recognition time;
- Time of motion execution.

Different methods to measure PMR are possible the selection of which depends on the task to be solved. But in sports particularly in basketball, handball, volleyball when it is necessary to take or tackle the ball is important PMR adequate to game situation. By the proposed method [4, 5] basketball and handball players were tested. According to the results of investigation positions of the players in the field were corrected.

It is known that simple reaction time does not depend on other physical abilities of a human [8] but general PMR rate depends on psychical and motoric abilities of a human. The investigation results showed that the time for situation evaluation is longer when the motoric task is more difficult i.e. when a sportsman has to jump up.

PMR movement time should depend on rate quickness abilities of a human, i.e. on the fact how quickly he/she is able to make a movement. These investigations have had confirmed this statement and indicated that the speed of a movement depends on dynamical force of a human. Dynamical force is expressed as the maximal force development rate, i.e. as maximal value of the force derivative in time: F'_{maks} or $(dF/dt)_{maks}$. The speed of a single motion is strongly related with dynamical force.

The dynamograms of two sportsmen A and B registered at making the highest speed jump are shown [6]. Mass center speed at contact loss with the support instant for both sportsmen is the same – about 2,3 m/s, both of them made the same height jump-up. Speed at the movement end point is defined by the force impulse but not the movement duration. Nevertheless it is seen from dynamograms that sportsman A makes the jump at higher speed so he will reach the ball quicker that sportsman B.

Psychomotoric reaction was investigated only making 10 cm and 20 cm height jumps-up. Previously the volleyball players were tested setting the task to make 30 cm jumps-up [4]. But such jumps can be made only by good spring distinguished sportsmen.

Making 10 cm jumps-up correlation between components of psychomotoric reaction and parameters of jump-up dynamogram is weak (table 2). This indicates that such height is not enough for the investigation of the relation of psychomotoric reaction and spring of the sportsmen. But when making 20 cm jumps-up strong correlation between PMR movement rate and relative dynamical force(r = -0,60) as well as duration of knee bending phase is observed(r = 0,87).

Quite significant negative correlation between dynamical force of protractile muscles taking part in movement and PMR movement time shows that dynamical force is one of the most important parameters defining the jump-up duration. It is worth mentioning that previous investigations showed that the importance of different jump-up parameters making movement tasks of different motivation (making the highest jump or making the highest speed jump) is different [5]. Making the highest jump the result is defined not by dynamical force but by force impulse magnitude at take-off.

Strong positive correlation between knee-bending phase duration and PMR movement rate indicates that knee-bending is important negative but inevitable factor defining the jump-up duration. Making jumps-up with knee-bending protractile muscles of the legs and back take part in the movement. Aiming to shorten the movement duration the duration of knee-bending phase should be shortened also. This can be achieved increasing dynamical force.

Conclusions

1. PMR determination method modeling game situation allows evaluating the dependencies of psychomotoric reaction and its components on the complexity of movement task.

2. PMR latent and situation recognition time is greater when a jump-up is to be made but does not depend on the jump-up height.

3. PMR movement time depends on dynamical force but does not depend on other parameters of jump-up.

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