EVALUATION OF HUMAN MOVEMENT PROPERTIES DESIGN

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Summary: For illustration of approach about how to systematically revise and improve any human movement level of performance, especially in top level sports, artistic performances, hard industrial tasks, etc. standing long jump is used as example. As important parameters that can lead to a jump optimization, reduced human dynamical inertia moment transition and vertical center of mass position were tracked and presented in qualitative mode. By creating best cause-consequence correlation improvement of jump performance is possible only if movement properties transition show weaknesses. Establishing connection of human body segments movement with causation to the center of mass trajectory may provide further improvements.
Keywords: human movement optimization, motion performance

1. INTRODUCTION

Considering human movement as process with final accomplishment, applying the movement design can produce performance improvements, reduction of energy consumption, reduce injuries occurrence, etc. That means that optimization of movement properties can cause improvement in effectiveness of present human physical abilities, but over that level improvement can provide only psychophysical abilities improvement.

From ergonomic point of view, investigation of parameters for human movement and abilities to perform it is not the only aim, but importance is undeniable. Furthermore, ergonomic principles demand that motion designers should take care about all human work details that can reduce fatigue, prevent health disturbances, improve comfort, create working atmosphere etc. For the purpose of evaluation of human standing long jump properties comparation of motion properties should take place. The human body joints trajectories are describing the movement itself, but exact way to reach final position is not completely established. Every movement can offer variations on how to do it, but case where human being can produce best performance with its psychophysical potentials, and of course, with intact health is the wanted result. Beside, ergonomics of human movement is even more important in everyday life especially to prevent injuries and any health disturbances, along with intention to make life easier and more comfortable, beside effectiveness.

Movement itself can be described as a task with starting and finishing human body posture (position), and of course, reason to perform it. Alterations of mentioned movement performance are very wide ranged. Considering such a movement with

altered level of human body activation, difference in overall performance can be noticed. Even though, only optimal human body activation can produce best result, which can be concluded from ever present difference in task completion valuation.
For successful design process it's important to articulate movement goal and define final satisfactory execution level. Even more, for the movement perfection design acquisition of all the knowledge that can serve as important information is needed. If motion can be described by human body trajectory with involved psychophysical activation, interrelation with performance should be present. General idea of how to improve movement realization is aimed to optimal execution through established best relation of movement parameters. In analyzed movement may be more important to consider all the parameters that are relevant to create gain in overall performance than to track all of them. Also, to optimize movement parameters that are important and influential, movement analysis should take place. It is obvious that movement itself depends on its complexity which causes trajectory of every single human joint involved. Problem is to track trajectories for all involved joints, but also to determine their relevance to final movement accomplishment.
In this paper is presented approach with idea of presenting human movement as the process that can be optimized, where every phase of human movement has its own explanation, if not purpose and goal.
What would lead to a better performance, or even more interesting, how to provoke it?
Answer to that intention is in finding interrelations between important parameters values through phases of movement and achieved effects on overall trajectory. Change in selected body segments trajectory and kinematics can cause different trajectory of body mass center, which may cause change in overall achievement. Transition of relevant parameters values through phases creates image on movement itself, where parameters also show their correlation. If unoptimized section of movement can be noticed and corrected, gain in overall performance can occur. Unoptimized section of movement is considered as any involved influence on the movement parameters that cause dissatisfying task completion.

2. METHODS AND RESULTS

2.1 Selection of tracked movement properties

For the movement properties selection is, as earlier mentioned, important to understand which of parameters can influence motion performance. The scope should be oriented to the most important parameters rather than all of them. As first phase of analysis it is much easier to track one pair of parameters that seem to be correlated than those that influence selected pair. Since vertical center of body mass position presents one significant coordinate of trajectory for analized jump, to create trajectory is important horizontal coordinate, respectively. Motion of human body segments during jump execution have influence on jump trajecory considered as body mass center trajectory as well as to the dynamical inertia moment, most often reduced to the same center. Since there is assumed explainable correlation, as another parameter we'll chose reduced human dynamical inertia moment. This selection of parameters should provide transition of jump execution parameters with influence to changes in body mass position and dynamical properties, considered as the pair that can lead to a jump optimization, if not just for observation.

2.2 Procedure and results

Performed and analized standing long jump is selected to be just an example for this debate, so the optimal evaluation of parameters are not primary goal. There was just one jump execution, which may be used for this hypothetical approach. Calculation of selected parameters is evaluated for male subject, while the jump is filmed in equal time sections to obtain sequences of jump in time related dependence. Results shown as qualitative distribution in figures are without exact numbers, since their anthropometrical dependence is not of prime importance to this paper. Anthropometrical and other psychophysical parameters should not influence this study rather than convenience of shown motion design procedure. The way of performing standing long jump is as is, without any corrections.

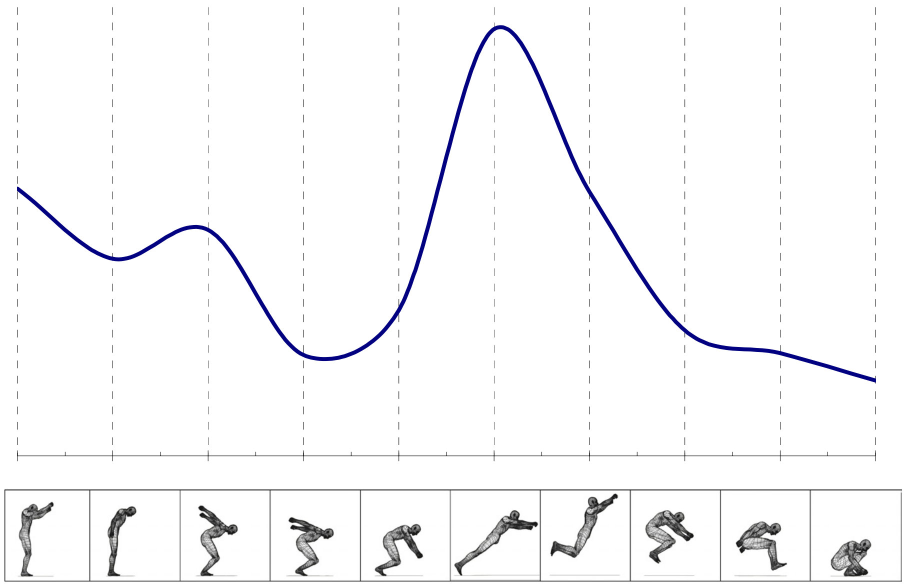

Figure 1. Transition of dynamical inertia moment reduced to the center of mass

Performed standing long jump was filmed, from standing starting position before jump to the fully landed, presented as 10 photos. Between photos is equal time interval, so the transition of sequences is uniform. Dynamical anthropometry is applied for calculation of human body properties before execution of jump, but the parameters as body properties assumed to change.

The center of mass is calculated for every single sequence of the jump, providing information of its change in vertical position, as well as information for calculation of dynamical moment of inertia reduced to the body mass center, in kgm^2.

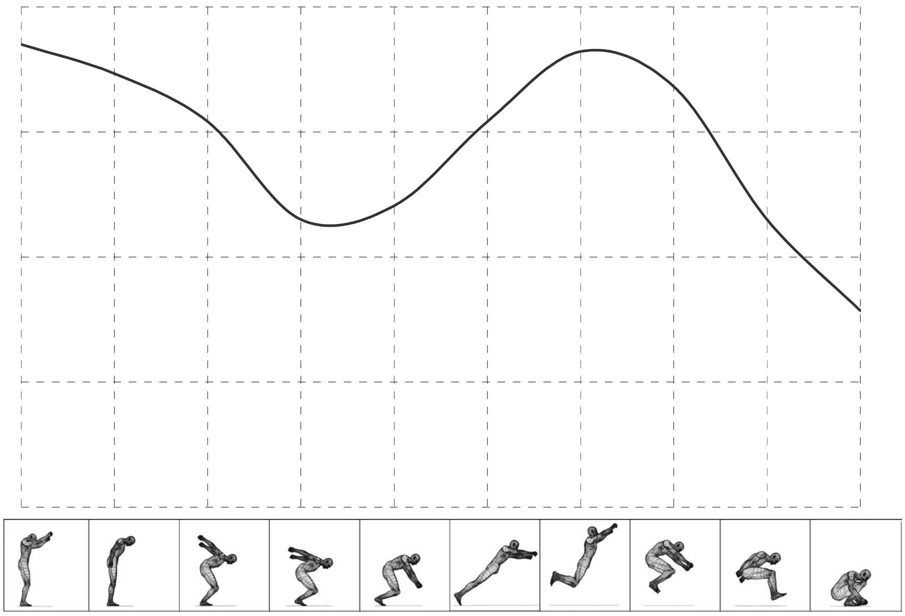

Figure 2 Vertical body mass center transition

Figure 1. presents transition of dynamical moment of inertia reduced to the body mass center of each sequence, which is represented by photo sequences below the transition curve.
Figure 2. presents vertical position of body mass center transition through sequences, where position is defined as height, m.

Both of presented figures showing image of real movement and its consequences, in order to make design of jump possible. Correlation of motion sequence with related parameters as well as their transformation is creating ground for parameters change that will make difference in jump length, if considered as jump kriteria . Kinematics of the jump is not measured or calculated, which would cause expansion of analysis, what for this phase of analysis is not wanted. Next phase of design is to analyze evaluated results, preparing to understand how to evaluate jump parameters.

3. DISCUSSION WITH CONCLUSIONS

Since every motion sequence has its own properties, possible explanation for presented transformation may have implication for jump length improvement, beside overall movement mastering. So, we just created aim of the design- to make jump longer. In general, if we are about to create jump pattern which will make longer jump, subject must make some adaptations of jump execution sequences which will cause improvement. Primarily we shall analyze each body segment movement purpose and effect, but also its influence to the trajectory of body mass center. Since each body segment position and posture influence overall inertia moment reduced to the center of mass, understanding of presented figures seems to offer a lot more than to be just movement parameters.

Figures are presented with jump transition postures respectively, so for the next step let's describe what we can see.

The first phase of the jump is energy accumulation, which is analogue to spring compression. That is shown as transition of postures from first to the approximately fourth of ten photo sequences, which ends with lowest center of mass position. The second phase of the jump is take-off, where all the accumulated energy should expand, making third phase named flight as long as possible. That is shown as transition of postures from lowest center of mass position to the approximately sixth of ten photo sequences, which ends with leaving the foot ground support. Finally, jump will end when the subject's center of mass stops in fourth phase which includes flight and landing. Separation of those sequences of fourth phase is questionable, so we'll let it be as is.

Subject has limited resources of energy and ability to produce kinetic energy, but to produce longer jump it has to use it the best possible way. Mass properties of the subjects body are considered constant through the jump, but body inertia moment isn't. The last phase of the jump flight is preparation for landing, and therefore it's almost impossible to make a lot difference in the body segments movement. So, beside takeoff phase as kinetic energy accumulation phase, only sequence of the jump where subject can influence the jump itself is the first part of the fourth phase. Beside that, the angle of the jump execution relative to the horizontal array will also make difference, but this is outside parameter. His evaluation can provide another improvement in order to optimize jump trajectory, but also to influence energy levels of the jump. Since we are about to analyze weaknessess of the jump execution, this parameter is usefull for the next phase of the jump mastering.

As shown in Figure 1., subject is minimizing his moment of inertia prior to jump while lowering his center of mass. At the last moment of take-off he's creating the largest possible extension of body and activated muscles with intention to create best effort, which result with maximal available inertia moment. Also, period of minimizing the inertia moment after the take-off is not as short as maximizing phase before it, so the center of body mass height loss seems to be intensive in the second part of fourth phase. If subject can minimize the inertia moment as fast as it is maximized prior the take-off, the flight may last longer, mostly with idea of keeping achieved energy level as long as possible. With alteration of jump angle related to horizontal array set to be optimal, jump may become more efficient, or just improved. In the Figure 2. is possible to notice that the phase of take-off produced short period of increasing body mass center height comparing to the following flight and landing phase. Explanation may be that jump is performed with inadequate jump angle, with poor energy level achieved or with high energy losses. Energy transformation through jump phases may be optimized, showing that selected parameters should be monitored with assistance of few more relevant parameters. Exact evaluation of presented curves for jump properties change should involve several jump type executions, where properties change can be compared and evaluated with caused jump length.

This shows that assumed connection of the body mass center trajectory with inertia moment at that time, may become very usefull for jump performance valuation.

Alteration of experiments or numerical models can provide even more information and cause- consequence relations, but the relevance of this analysis is fulfilled. In simplyfied analysis of motion task, we find that every sequence of the movement has its description and purpose, can have implication to the next phase and to the final accomplishment. Also, to improve human movement, we need to understand it, to define the aim of design for it, to define criteria of evaluation, to compare the parameters with motion sequences and finally, to create list of possible weaknesses. Since the human body may have its physiological top limits, the best option for motion improvements is in efficiency of resources.

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