AGE-RELATED DEVELOPMENT OF RUN-UP VELOCITY ON VAULT

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Abstract

The run-up velocity on vault is described in many publications as an important factor to generate the energy for the subsequent motion segments of a vault. For a high run-up velocity both, biological backgrounds and empirical investigation show a steady increase in speed until the start of men's senior gymnastics age. Different mechanisms are responsible for this circumstance. Thus the increases of the running velocity during childhood and up to pubescence are due to primarily informational or coordinative development. From the beginning of puberty the faster sprint performance, especially in male gender, can be explained by conditional developments based on changed hormones level. To proof the explanations we compared the age related velocity in different stages of motor development, using run-ups of the last four years at various high level competitions. There is an increase in the velocity up to the end of men's junior gymnastics age, followed by stagnation in senior age. The speed increase in pubescence and adolescence do not differ. Therefore coordinative and conditional factors determined the development of run-up velocity equally.

Keywords: *age-related, development, run-up velocity, vault, men's gymnastics.*

INTRODUCTION

The competitive sports in general, especially gymnastics, are characterized by a continuous development and therefore constantly growing prerequisites on athletes. To meet these requirements a correspondingly high expression of performance parameters is needed and has to be supported with the uncovering of reserves in performance development.

A Vault consists of seven sections, run-up, hurdle, take-off, first phase of flight, support, second phase of flight and landing (Dillman, Cheetham & Smith, 1985; Sands, 2003a). One possible reserve on vault is seen in the expression of the approach velocity, whose great importance for a successful execution is mentioned in many specific gymnastics publications (Takei, 1988; Sands, 2000; Tashiro, Takata, Harada, Kano & Yanagiya, 2008). Krug (1986), Hess (1993) and George (2010) mentioned the creation of the necessary energy requirements in the preliminary motion stages (run-up, hurdle, take-off) to fulfil the requirements of a difficult vault as well as possible. Brüggemann and Nissinen (1981) calculated a significant correlation of the approach velocity with height and width of the 2nd Phase of flight in handspring vaults. There is a positive correlation between run-up speed and score (Sands & Cheetham, 1986; Takei, 1988; Sands & McNeal, 1986; Takei, Blucker, Dunn, Myers and Fortney, 1996). Krug, Knoll, Köthe and Zocher (1998) and Tashiro et al. (2008) also point out, that a faster run speed benefit a higher score. Own studies (Brehmer, Naundorf, Knoll, Bronst & Wagner, 2008) show a weak correlation between the run-up velocity of forwards vaults (according to the International Code of Points (Federation international de Gymnastique, 2009) jumps are divided into five groups, three are relevant. Group III (handspring type) and IV (Tsukahara/Kasamatsu) are forward type vaults, in group V (round off entry/Yurchenko-Type) the backward jumps are classified.) in men's artistic gymnastics and difficulty score (D-Score: r = 0.39) and also to the final score (F-Score: r = 0.39).

The measurement of run-up velocity is common in training and competition. In senior elite gymnastics necessary run up velocities were published, but measured with different methods (Takei, 1988; Sands, 2000; Tashiro, et al., 2008; Velickovic, Petkovic & Petkovic, 2011). The assessment of the run-up velocities in youth and junior age however is still considered as problematic. In particular, the growth rates in the different ages and stages of motor development until puberty are of interest to the training practice. Currently there is a lack of specific reference values in the trainability of locomotive speed.

Speed of limb movements described as a physical ability (Fleishman, 1963) is a coordinative and conditional determined performance requirement and important for run-up velocity. Hohmann, Lames and Letzelter (2002) assume that speed is based on the quality of information processing. Thus the basic speed is determined by the neural control and regulation processes (time programs) and inter-muscular coordination (Grosser, Starischka & Zimmermann, 2004). The foundation for improving speed is a highly functional interaction between individual muscles (Nöcker, 1989) and the increase in the sub-areas of neuromuscular control and regulatory processes as well as the involved morphological structures and respective operating functional-energetic processes (Grosser et al., 2004).

At the same Grosser et al. (2004) attributed the complex speed capability primarily to the speed strength. The great improvement in speed (Schmidtbleicher, 1994), which is largely dependent on force, is caused by the modified trainability of muscles. From a biological point of view, force and speed associated mainly with the production of hormones, especially testosterone. Admittedly, testosterone is formed not before the onset of puberty in sufficient quantities. At the acceleration phase, which marks the approach on vault, the speed strength has a decisive role (Martin, Nicolaus, Ostrowski & Rost, 1999).

Grosser et al. (2004) favour speed training from about the age of 7 as useful and recommended. Schmidtbleicher (1994) argues for a training of complex frequency speed-oriented movement skills in prepubertal phase, since after Bauersfeld and Voß (1992) all necessary coordinative conditions for the development of fast time programs are already given in this age. For Winter and Hartmann (2007) the speed ability pertains to those motor skills that are formed early in motor development and are already completed at the end of puberty.

Several publications pick up the issue of running velocities in empirical studies. Crasselt, Forchel, Kroll and Schulz (1990) documented the developments of various physical and athletic performance among schoolchildren in large-scale long-term studies. They (Crasselt et al., 1990) checked the development of locomotion speed with the help of the 60-meter run. Bös et al. (2009) extracted their findings from a nation-wide cross-sectional study. They use the 20-m sprint as the representative of locomotion speed in their tests of motor functions. An almost constant growth from the age of 6 respectively 7 to the age of 17 was recorded in both studies.

Previous sport – specific considerations have been limited to rough divisions in different age-ranges, but without providing precise age information. Brüggeman and Nissinen (1981) for example subdivided into groups of young gymnasts (schoolboys, 6.79 m/s velocity at first board contact), A-/B-squad (7.40 m/s) and world class gymnasts (7.98 m/s) and found evidence that largest run-up velocities are found in more high-performance groups. Sands (2000) investigated the maximum approach velocity and divided his sample into categories including juniors and seniors. As a result of his analysis, he noted that the seniors (7.41 m/s) run significantly faster than the juniors (7.06 m/s).

From the current literature with relevance to the development of locomotion speed (Crasselt et al., 1990) or the action speed (Bös et al., 2009), can be deduced a steady and almost linear increase in running speed till the age of 18. Thus an increase in running speed is apparently linked to an increasing (training-)age. However, there were no guidelines how large annual rates of development should be, not to mention at what age an exercise of speed is particularly beneficial.

According to recent findings on the approach on vault are coordinative-informational as well as conditional-energetic parameters. However it is not sure if one of the two factors has a greater influence on the development of run-up speed in gymnastics. So it is important to examine the research question whether and if so, when and what influential factors play a major role in gymnastics. This deficit of knowledge is to be examined more closely in this article. To answer the research question we use one popular way to classify the stages of motor development in Germany by Winter and Hartmann (2007). This classification is shown in Table 1. Findings on the development of the run-up speed should allow a classification of the velocity and their development rates.

Table 1. *Stages of motor development with age-range and characteristics (modified from Winter & Hartman, 2007).*

Stages of motor development	Age-range		Competition rules
	from	to	
“middle childhood”	6	9	
“late childhood”	10	12	regional and national rules for youth gymnastics
“pubescence” (early adolescence)	13	14	
(late) “adolescence”	15	18	Code of points (FIG, 2009) Junior competition
“early adulthood”	19	35	Code of points (FIG, 2009), Senior competition

METHODS

Participants

To answer the research question, a total of 1.165 runs by male athletes aged from 12 to 39 years (only the year of birth is decisive for their classification). were recorded in important national competitions (German Youth Championships, German Championships), international tournaments in junior level (International Junior-Team-Cup Berlin), as well as competitions at international level for seniors (World Cup Cottbus and Stuttgart, World Championships 2007).

Some athletes took part in a competition more than once a year, so the fastest approach of each gymnast per year was selected. To ensure a sufficient number of participants in any age, the age-range was limited from 12 to 25 years. Furthermore this age-range contains the relevant section of changes related to development and training. Focusing on elite gymnastics and in order to incorporate only the fastest athletes in the analysis a median split of the velocity per year was performed. Thus the remaining number of approach velocities amounts to 335, with a total of 246 different athletes (Table 2).

Apparatus

For calibration and measurement a laseroperated velocity guard (LAVEG) was used. In all competitions the approach velocity recorded using the same technique under similar conditions (Figure 1) with a calibration before every competition. In each case the LAVEG set in line with the approach, facing the vaulting table.

Table 2. *Overview of the number (n) of runs in each age class in reduction of the data on the fastest run-up per year per athlete, structured according to stages of development.*

	"late childhood" & "pubescence"			"adolescence"				"early adulthood"							Total
Age	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
n	47	34	32	35	30	40	40	9	16	13	17	15	11	6	335

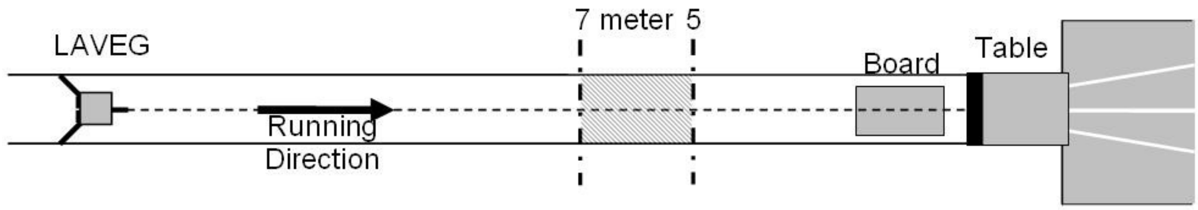

Figure 1. *No dimensional sketch of the velocity measuring system in gymnastics competition.*

Data analysis

Specifically developed software was used for the evaluation of the measured displacement data. For the following analysis of the run-ups, only the average speed between the 7th and 5th meter ($v_{7\text{-}5}$ in m/s) before the vaulting table is of interest. Leirich (1979) determined the range between six and five meters in front of the vaulting table as the range which is directly in front of the hurdle. Data from other investigations (Trillhose, 1995; Brehmer & Naundorf, 2009) support the selected 2 m-section.

The statistical analysis is carried out using SPSS 17.0 and MS Excel 2003. To estimate the run-up velocities of young gymnasts and their underlying mechanisms three phases have been separated, according to the stages of motor development (Winter & Hartmann, 2007). These stages are the "late childhood" and "pubescence" (12-14-year-olds), the "adolescence" (15-18-year-olds) and the "early adulthood" (19-25-year-olds). In addition to descriptive statistics, a regression analysis is carried out for the age-ranges described above.

RESULTS

The means of the run-up speed for the development phases are 7.3 m/s (12-14-year-olds), 8.0 m/s (15-18-year-olds) and 8.5 m/s (19-25-year-olds). The values listed in Table 3 for the selected stages.

It can be assumed that there is a basic increase across the stages of motor development. This is confirmed by data from the linear regression (the linear regression is the simplest relationship between interval-scaled data and is described by the equation $y = b * x + a$. The regression coefficient b is the expression for the increase of the line and the constant a is the intersection with the y-axis)(Table 4) that prints the growth rate per year for the start of each development phase.

The increases (b) of the regression lines are almost identical (the run-up speed [m/s] is given with one digit after the decimal point (accuracy 10 cm/s), so the regression coefficient of 0.16 or 0.19 has to be evaluated as equal) at the 12- to 14-year-olds ($b = 0.16$) and 15- to 18-year-olds ($b = 0.19$), with comparable regression constant (a). In „early adulthood" (19-25-year-olds) a significantly increase ($b = 0.02$) is no longer observed (Table 4).

The regression is shown in Figure 2, using a scatter plot, which contains the respective regression lines for the development phases. In "late childhood" and "pubescence" (12-14-year-olds) the increases of the velocity are approximately the same as in the following section of the "adolescence" (15-18-year-olds). In "early adulthood" the starting rate nearly stagnated at a high level (> 8.1 m/s).

Table 3. *Number (n), minimum (MIN), maximum (MAX), as well as mean ($\bar{x}$) und standard deviation (s) of the collected run-up velocities ($v_{7\text{-}5}$).*

	Age-range of development phase			Total
	12-14 years	15-18 years	19-25 years	
n	113	135	87	335
MIN (m/s)	6.9	7.4	8.1	6.9
MAX (m/s)	7.9	9.1	9.2	9.2
$\bar{x}$ (m/s)	7.3	8.0	8.5	7.9
s	0.2	0.3	0.2	0.5

Table 4. *Number (n), regression constant (a) and regression coefficient (b) with confidence intervals (CI) of the collected run-up velocities separated in development phases.*

	Age-range of development phase		
	12-14 years	15-18 years	19-25 years
n	113	135	87
a	5.27	4.82	8.13
b (CI 95%)	0.16 (0,12 - 0,20)	0.19 (0,15 - 0,23)	0.02 (-0,01 - 0,04)

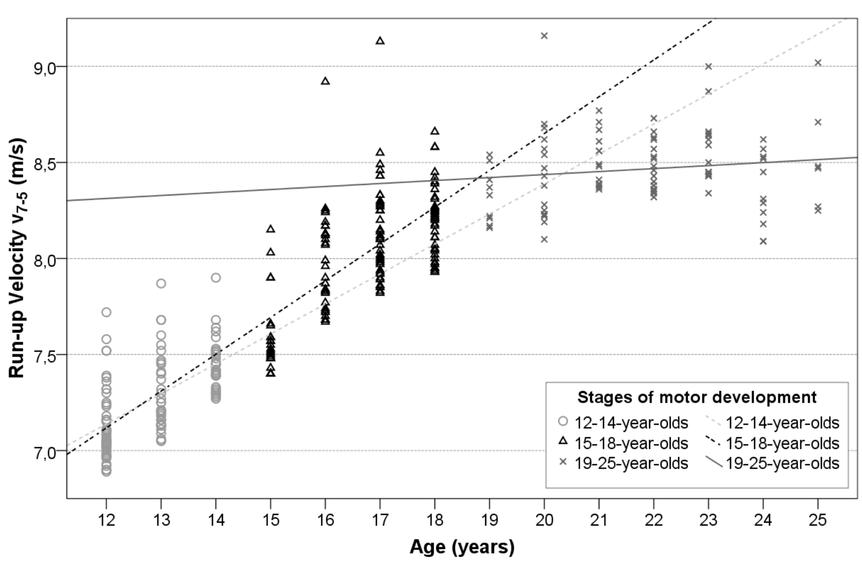

Figure 2. *Scatter plot with marked development phase and associated regression line.*

DICSUSION

The results show an increase in the approach velocity in ”late childhood“ and ”pubescence“ ($b = 0.16$) and in “adolescence” ($b = 0.19$, see Table 4). Keeping the overlapping confidence intervals (CI 95%) in mind the growth rates of these two development phases are approximately equal. Based on the results, the informational-coordinative and the conditional-energetic factors are equal in their influence. Thus the results confirm the assumption that both, the neuromuscular control and regulation processes and the energetic components play an equal role in the improvement of the speed. Acquired elementary speed skills in prepubertal phase such as the speed of action and speed of frequency (Grosser et al., 2004; Sands, 2003b) are also important factors. Developmental changes in puberty, such as the increased formation of testosterone and the resulting improved trainability of the muscles (Schmidtbleicher, 1994) and the assumed dominant significance of the speed-strength development (Winter & Hartmann, 2007), have therefore no major impact on the run-up speed. Training should pay attention to the mechanisms of the stages of motor development. In prepubertal age coordinative aspects such as frequency and action speed should be developed as well. After puberty training should be focused on strength development to use the hormonal conditions. .

After an initial increase a stagnation ($b = 0.02$) of the performance development could be observed with entry into the senior level. The absence of increments confirms the conservation of physical performance (Winter & Hartmann, 2007) in the literature.

The present results of the regression analysis provide the opportunity of assessing the individual rates of development. Annual amount of increase of athletes’ velocity can be compared and classified with the regression coefficients. A corresponding comparison of the actual development with the development of the vaulting velocity on the basis of the determined regression coefficients (for the prediction of development, the value of the first recording with the corresponding regression coefficient for each development phase are added and plotted in the chart) (b) is exemplified in Figure 3.

The performance of gymnast 1 und 2 is below the reference line. Gymnast 2 had a good development, but did not reach the reference line because his starting level is too low. The youngest gymnast (gymnast 3) shows an unsteady increase of the velocity. Nevertheless he is on the reference line. With the help of these examples becomes clear that the development is rarely as constant as shown by the prognostic data. We have to note critically, that the presented increasing rates correspond only to their respective stage of development. Therefore, the rates could not be valid for each age. For more accurate findings in the future a separately consideration of all ages is necessary.

CONCLUSIONS

In this paper, the age-related development of run-up speed on vault was demonstrated. The analysis of the approach velocity give a basic possibility to classify the vaulting velocity from ”late childhood“ to ”early adulthood“, and thus the opportunity to assess the individual performance and performance development of the athletes. The present data show a constant increase of the run-up speed till the senior age. In ”late childhood“ and ”pubescence“ (12 to 14 years, $b = 0.16$), and in ”adolescence“ ($b = 0.19$) nearly equal rates of development are detectable (see Table 4). In relation to the development of run-up velocity in gymnastics neither the informational-coordinative nor the conditional-energetic factors have a dominant role. An increase of the vaulting velocity in ”early adulthood“ is no longer recorded (Table 4 & Figure 2).

However, for the competitive sport in male junior gymnastics we can make a note that performance increases of about 0.2 m/s per year are classified as average.

This allows the coaches to compare the development of their athletes with the average growth rates and consequently evaluate the effectiveness of the training. To improve the running speed, gymnastic coaches use special training resources, in particular athletics (Brown, Ferrigno & Santana, 2000; Dintiman & Ward, 2003). In this regard coaches have to keep in mind the advice of Voß, Witt & Werthner (2007) that training only leads to success, if the close relationship between technique and strength training is respected. Thus both, coordinative and conditional aspects have to take into account.

Some authors (e. g. Grosser et al, 2004; Schmidtbleicher, 1994, Winter & Hartmann, 2007) expect high growth rates in speed of limb movements before the analyzed age-ranges. The elite gymnastics career starts about the age of five. There is no research known in this age-range. In addition, investigations in the women's artistic gymnastics and comparisons with other speed-oriented sports could give further information about the trainability of the cyclic speed.

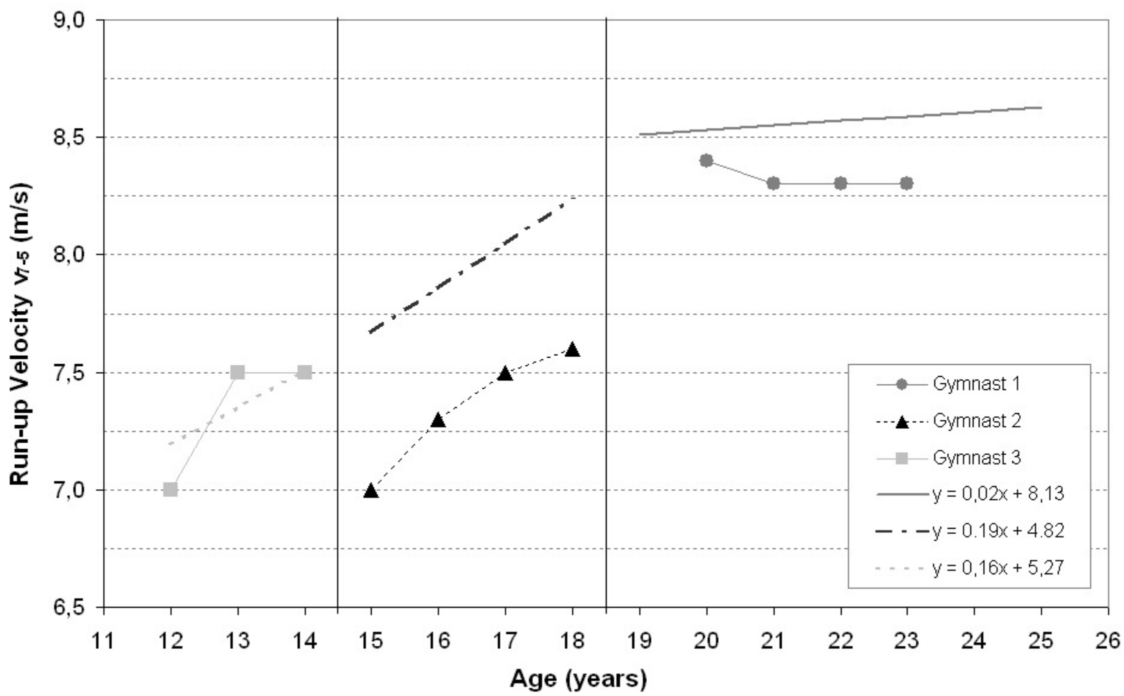

Figure 3. *Comparison between real (gymnast x) and predicted development (gymnast x + b).*

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