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Relationship of Isokinetic Leg Press Strength to Sprinting Performance in Junior Elite Volleyball Players

Zusammenhang des isokinetischen Kraftmaximums in einer Beinpresse mit der Sprintleistung von Nachwuchsvolleyballern

ORIGINALIA

ACCEPTED: August 2019
PUBLISHED ONLINE: September 2019
DOI: 10.5960/dzsm.2019.394

Möck S, Wirth K. Relationship of isokinetic leg press strength to sprinting performance in junior elite volleyball players. Dtsch Z Sportmed. 2019; 70: 203-208.

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Summary

- **Problem:** Sprinting represents a relevant task in many sports. The correlation of sprinting performance and squatting strength (1RM) has been shown in several investigations. Correlations with maximum strength in a linear isokinetic leg press are still pending. Since different devices produce different relationships and rotational isokinetic measurements show conflicting results, further evidence is needed.
- **Methods:** 23 male German junior elite volleyball players (16.72±1.07 years, 193.0±0.07 cm, 79.86±7.46 kg) were investigated. They performed sprints up to 30 meters and isokinetic leg press testing at 2 different velocities (0.1 m/s and 0.7 m/s). In the sprint the following times were recorded: 0-5m, 0-10m, 0-20m, 0-30m, 10-20m, 20-30m.
- **Results:** The strength tests revealed mean values of 4389.83± 514.95 N (0.1 m/s) and 2690.83±370.97 N (0.7 m/s), while the sprint test showed a mean performance of 4.34±0.17 s (30 m). Correlational analysis showed significant correlations (p<0.05) for relative strength at 0.1 m/s with sprinting performance up to 30m only (r=-0.404 to -0.485), whereas only relative strength at 0.7 m/s showed significant correlations (p<0.01) with the following sections up to 30m (r=-0.536 to -0.747).
- **Discussion:** The strength of the lower extremities is a basic requirement for short sprints and should be considered in training. Additionally, in strength testing, different manifestations of strength performance should be taken into account.

KEY WORDS:
Power, Movement Speed, Strength Testing

Zusammenfassung

- **Problem:** Der Sprint stellt eine leistungsentscheidende Aufgabe in vielen Sportarten dar. Korrelationen der Sprintleistung mit dem Einerwiederholungsmaximum (1RM) in der Kniebeuge konnten in mehreren Untersuchungen gezeigt werden. Zusammenhänge unter Verwendung einer linearen isokinetischen Beinpresse stehen bisher noch aus. Da unterschiedliche Testformen unterschiedliche Zusammenhänge zeigen und rotatorische isokinetische Messungen widersprüchliche Ergebnisse liefern, sind weitere Ergebnisse notwendig.
- **Methoden:** 23 männliche deutsche Nachwuchsvolleyballer (16.72±1.07 Jahre, 193.0±0.07 cm, 79.86±7.46 kg) wurden untersucht. Sie absolvierten Sprints bis 30 Meter Länge und Kraftmessungen in einer isokinetischen Beinpresse bei 2 verschiedenen Bewegungsgeschwindigkeiten (0.1 m/s und 0.7 m/s). Im Sprinttest wurden die folgenden Zeiten erhoben: 0-5m, 0-10m, 0-20m, 0-30m, 10-20m, 20-30m.
- **Ergebnisse:** Die Krafttests offenbarten Mittelwerte von 4389.83± 514.95 N (0.1 m/s) und 2690.83± 370.97 N (0.7 m/s), während der Sprinttest eine mittlere Leistung von 4.34±0.17 s (30 m) aufzeigte. Die Korrelationsanalysen zeigen signifikante Zusammenhänge (p<0.05) zwischen dem relativen Kraftmaximum bei 0.1 m/s und der Sprintleistung bis 30m (r=-0.404 to -0.485), während das relative Kraftmaximum bei 0.7 m/s Zusammenhänge (p<0.01) mit den Abschnitten bis 30m lieferte (r=-0.536 to -0.747).
- **Diskussion:** Die Maximalkraft der Beinextensoren stellt eine grundlegende Leistungsvoraussetzung für kurze Sprints dar und sollte im Training entsprechend berücksichtigt werden. Darüber hinaus sollten in der Diagnostik verschiedene Erscheinungsformen der motorischen Kraft sorgfältig bedacht werden.

SCHLÜSSELWÖRTER:
Schnellkraft, Bewegungsschnelligkeit, Kraftdiagnostik

GERMAN JOURNAL OF SPORTS MEDICINE
Deutsche Zeitschrift für Sportmedizin
VOLUME 70

Scan QR Code and read article online.

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Introduction

Muscle strength and power display important requirements for performance in various sports. For ballistic movement tasks the relationship between performance and maximum strength depends on moment duration and the resistance to be moved, but in general it persists (10, 30, 32, 33, 40). And yet it must be pointed out that different relationships with ballistic actions come about when different methods are used to test for maximum strength (5, 8, 20, 23), which impedes the judgement of the real relationship. Regarding strength training interventions, different training effects on speed-strength performance can be observed as well. Wirth et al. (38) for example compared the two training exercises back squat and leg press with similar training regimens in regards to their effect on vertical jumping performance. The squat training group increased their performance in squat- and countermovement-jump significantly, while training in a leg press led to no significant changes. Fitting to

Table 1

Descriptive data of the sprint- and isokinetic strength tests. BW=bodyweight; LP100=leg press strength at 0.1m/s; LP700=leg press strength at 0.7m/s.

	N	MEAN	SD	MAX	MIN
5m[s]	23	1.02	0.04	1.08	0.95
10m[s]	23	1.77	0.06	1.86	1.68
20m[s]	23	3.07	0.11	3.29	2.92
30m[s]	23	4.34	0.17	4.70	4.06
0-10m[s]	23	1.77	0.06	1.86	1.68
10-20m[s]	23	1.31	0.06	1.43	1.22
20-30m[s]	23	1.26	0.07	1.41	1.13
LP100[N]	23	4389.83	514.95	5243.00	3424.00
LP100rel[N/kg BW]	23	55.15	5.83	66.65	42.59
LP700[N]	23	2690.83	370.97	3354.00	2086.00
LP700rel[N/kg BW]	23	33.79	4.24	40.73	28.21

this observation, Silvester et al. (35) as well found a training in the squat to outplay a training in the nautilus compound leg machine to develop vertical jumping performance. Because of the different relationships depending on the used testing method (5, 8, 20, 23) and the different relationships among the several testing modalities for maximum strength (8, 18, 38), results cannot be transferred to other testing exercises, as mentioned before.

By now, using isokinetic dynamometry to test for strength capabilities rank among the widely used methods, especially in rehabilitation (6, 13, 14). Nonetheless, studies examining the relationships of maximum isokinetic strength with speed-strength performance are scarce and show conflicting results. Tsiokanos et al. (37) obtained significant relationships between maximum isokinetic torque of the leg extensors at different movement velocities and vertical jump performance, while the results of Österberg et al. (28) and Lehnert et al. (25) could not reassure these findings. Iossifidou et al. (21) as well could observe relationships between mechanical power at fast movement velocities and vertical jumping only, when corrected for effects of inertia. On the other hand, Ashley & Weiss (1) obtained significant relationships between isokinetic strength and vertical jumping by using an isokinetic multi-joint squat test. Regarding sprinting performance, Dowson et al. (12) performed single-joint isokinetic tests for knee-extensors, hip-extensors and plantarflexors and observed the highest relationships for knee-extensors at high movement velocities. In contrast, Bracic et al. (7) could identify significant correlations for hamstrings only, when investigating time to peak torque for quadriceps- and hamstring-musculature.

To the authors' knowledge, no data regarding relationships between sprinting performance over short distances and lower body isokinetic strength have been reported using multi-joint testing.

In volleyball, usually short distances have to be covered. With this reason, investigations on sprinting ability in volleyball players focus on distances up to 10m (16, 17). Nevertheless, Smith et al. (36) observed national team players to display significant greater 20m sprint performance than universiade volleyball players. This might be a factor influencing performance in rallies of long duration with long distances to cover. So it appears arguable, that maybe longer distances should be tested as well.

Methods

The aim of this investigation was to present the correlation between the maximum strength in an isokinetic leg press and the sprint performance over short distances. 23 male German junior elite volleyball players participated in this investigation. The maximum strength of the knee and hip extensors was determined via an isokinetic leg press. The sprint performance was measured over a course of 30 meters, in which times where taken by double-photoelectric light sensors after 5, 10, 20 and 30 meters, respectively.

The following quantities where determined: isokinetic leg press strength as well as the spiriting times 0-5m, 0-10m, 0-20m, 0-30m and sprinting times for sections 0-10m, 10-20m, 20-30m.

Subjects

23 male German junior elite volleyball players participated in this investigation. The mean age was 16.72±1.07 years, their height was 193.00±0.07 cm and weight 79.86±7.46 kg. The measurements were part of the teams regular performance testing and were carried out in the afternoon. All participants were free of injuries or other performance-limiting conditions. Each subject was informed of the experimental risks involved with the research. All subjects provided informed written consent. The research design was approved by the institutional review board. The study was carried out with respect to the use of human subjects and according to the Declaration of Helsinki.

Sprint Test

The sprint test was performed - after an individual warm up - over a distance of 30 meters on an indoor track. 5 attempts were measured with a rest period of 5 minutes between attempts. For time tracking a double-photoelectric light sensor system by Sportronic (Winnenden, Germany) was used, whose measurement error is <0.1% according to the manufacturer. The running times where detected after 5, 10, 20 and 30 meters, respectively.

The start was executed in an upright standing position with a distance of 50 cm behind first light gate. No commando was given and every tested individual started the test at an individually chosen point of time. A test-retest reliability of r=0.94-0.98 (p<0.05) is indicated for this test (22).

Isokinetic Leg Press Strength

Isokinetic leg strength was determined using the ISOMED2000 isokinetic leg press device (D&R Ferstl GmbH, Hemau, Germany) with a measuring rate of 200 Hz. The movement start was set to a knee angle of 90 degrees flexion with the movement end at a knee angle of 175 degrees (referring to 180 degrees as full extension). Maximal isokinetic strength was determined bilaterally at movement velocities of 0.1 m/s and 0.7 m/s. These velocities were chosen because Perrin (29) recommends testing several isokinetic movement speeds to examine an individual's strength capacities and Hemmling & Schmidtbleicher (19) found the isokinetic maximum strength at a knee angle of 90 degrees with a movement velocity of 0.1 m/s to correspond to 95% MVC at the same knee angle with a nearly linear relationship (isokinetic maximum strength at 0.7 m/s corresponding to 68% MVC). For each movement velocity, 5 attempts were measured with no commando given after an individual warmup.

Dirnberger, et al. (11) report a test-retest-reliability of ICC (Intraclass-Correlation-Coefficient)=0.907-0.978 for this device.

Statistical Analysis

The data was analysed using SPSS 11.5 (SPSS, Inc., Chicago, IL, USA). Kolmogorov-Smirnov test was used to check for normal distribution. As this test revealed no significant result, Pearson's product-moment correlation was used to determine the strength of the relationships. The level of significance for all tests was set a priori to $p \le 0.05$.

The isokinetic strength values were analysed both as absolute strength and strength normalized to body weight (relative strength).

According to Keiner et al. (22), the correlation coefficient was interpreted as follows: 0 = no correlation, $0<|r|<0.2$=very weak correlation, $0.2<|r|<0.4$=weak correlation, $0.4<|r|<0.6$=medium correlation, $0.6<|r|<0.8$=strong correlation, $0.8<|r|<1.0$=very strong correlation, 1=perfect correlation.

Results

The descriptive statistics are displayed in table 1. The leg press test revealed a mean of 4389.83 N with a standard deviation of 514.95 N for 0.1 m/s and a mean of 2690.83 N with a standard deviation of 370.97 N for 0.7 m/s respectively. For the sprinting, mean interval times between 1.77 s and 1.26 s with standard deviations between 0.06 s and 0.07 s were obtained. The summarized sprinting times displayed mean values between 1.02 s and 4.34 s with standard deviations between 0.04 s and 0.17 s.

The calculation of the correlations for the maximum isokinetic strength and the times for the sprint up to 30 meters revealed significant, medium to strong correlations ($p\le0.05$ to $p\le0.01$) predominantly for relative strength values (Table 2). For the slow isokinetic condition (0.1 m/s) only relative strength showed significant, medium correlations with sprinting performance. Absolute leg press strength at 0.7 m/s showed significant, medium correlations only with the longer distances while relative strength at 0.7 m/s showed significant, medium to strong correlations with all distances.

Accordingly, the calculation of the correlations for the maximum isokinetic strength and the times for the sprint sections revealed significant correlations ($p\le0.05$ to $p\le0.01$) predominantly for relative strength as well (Table 3). Relative leg press strength at 0.1 m/s showed significant correlations only with the first sections up to 20m, while absolute strength at 0.7 m/s only showed significant correlations with the later sections from 10m on. In accordance with the cumulated sprinting times, relative leg press strength at 0.7 m/s showed strong, significant correlations with all sections.

Table 2

Correlation coefficients of the absolute and relative strength maximum with the sprint times. *=p<0.05; **=p<0.01; BW=bodyweight; LP100=leg press strength at 0.1m/s; LP700=leg press strength at 0.7m/s.

	5M[S]	10M[S]	20M[S]	30M[S]
LP100[N]	-0.007	-0.110	-0.189	-0.122
LP100rel[N/kg BW]	-0.404*	-0.475*	-0.485*	-0.421*
LP700[N]	-0.197	-0.364	-0.460*	-0.474*
LP700rel[N/kg BW]	-0.536**	-0.684**	-0.729**	-0.747**

Table 3

Correlation coefficients of the absolute and relative strength maximum with the sprint sections. *=p<0.05; **=p<0.01; BW=bodyweight; LP100=leg press strength at 0.1m/s; LP700=leg press strength at 0.7m/s.

	0-10M[S]	10-20M[S]	20-30M[S]
LP100[N]	-0.110	-0.250	0.001
LP100rel[N/kg BW]	-0.475*	-0.441*	-0.272
LP700[N]	-0.364	-0.508**	-0.446*
LP700rel[N/kg BW]	-0.684**	-0.692**	-0.699**

Discussion

The aim of this study was to detect possible correlations between absolute and relative maximum isokinetic leg press strength at different velocities and sprinting performance. Significant correlations could mostly be found for relative strength. Interestingly, for the analysed sprint sections leg press strength at 0.1 m/s only showed significant correlations as relative strength value and only with the first sections, whereas the later sections only showed significant correlations with leg press strength at 0.7 m/s. Regarding both the calculated sections and the cumulated sprinting times, the observation can be made that only relative strength at 0.7 m/s produces strong, significant correlations.

Concerning the technical recommendations for sprinting (26, 34), the early phase in acceleration is said to last approximately for 20m, which are characterized by a predominant activation of the leg extensors. The following transition phase – in which velocity still increases – should be characterized by an increased use of the ischiocrural muscles. If one considers that propulsion via hip extension of the ischiocrural muscles demands for high stiffness at the knee joint (15), and that the latter has been reported with increasing running speed (24), the requirements on leg extensors – as synergists – increase to maintain the correct sprinting technique. Since the ground reaction times decrease during the acceleration due to the increasing running speed (26) the time to produce this stiffness decreases as well. These considerations appear congruent to the findings of this study that force production at higher movement speeds correlate stronger with sprinting performance in later stages of the course while force production at slow speeds only correlate with performance in the starting phase.

Regarding neurophysiological differences between the two testing conditions (0.1 m/s and 0.7 m/s respectively) the first eye-catching parameters are the different time frames to produce force. Several investigations have shown that different motor unit recruitment patterns are used to produce either a gradual increase in force up to a maximum value or a maximal rate of force development in a short period of time (2, 3). For explosive force production during a short time period largely synchronized motor unit recruitment with high firing rates can be observed (2) while fairly asynchronous motor unit recruitment can be regarded as advantageous when a maximal force value has to be produced (3). So the different movement speeds in the isokinetic leg press device could be regarded as different neuromuscular tasks. Nevertheless, Behm & Sale (4) have shown that intended rather than actual movement velocity determines the neurophysiological training response. Since the participants of this study received the instruction to contract as hard and explosively as possible in both the slow and the fast movement velocity, a rather synchronous activation is to be assumed.

Another observation that catches the eye is the great difference between the correlation coefficients regarding absolute and relative strength values. The relative strength values produce medium to strong correlations with mostly › significant values while absolute strength mostly shows weak to medium correlations with no significant values except for absolute strength at the higher movement speed correlated with sprint performance in the later sections. The observation that relative strength shows higher correlation with sprinting seems logical, since the own body acts as the resistance to be moved. Nonetheless, previous research shows higher correlation of absolute strength values than the present findings in different testing conditions (9, 27, 39). One explanation might be the investigated sample of the present study. Considering the descriptive data, a fairly homogenous performance level and anthropometry can be observed.

One limitation of the present study is the fact, that technical parameters of the sprint were not obtained. The size of the relationship between maximum strength of a muscle group and sprinting performance might be dependent on sprinting technique and therefore usage of the investigated muscle group. Whether the obtained results can be transferred directly to different populations might be a function of running technique.

Practical Applications

The present study highlights the relationship of maximal isokinetic leg press strength with short distance sprinting performance. The findings indicate that the maximum strength of the lower extremities' extensors displays a basic requirement for sprint performance over short distances and should be considered when designing training programs.

Additionally, when applying strength testing, the different manifestations of strength performance should carefully be taken into account. The results show, that one strength testing condition (i.e. one isokinetic velocity) might not be sufficient to assess an athlete's performance level fully.

Funding

This research did not receive any funding.

Conflict of Interest

The authors have no conflict of interest.

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