



Bundesinstitut
für Sportwissenschaft



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KINGS - Studie

Krafttraining im Nachwuchsleistungssport

(KINGS - Study

Strength Training in Youth Athletes)

Publikationen / Abstracts





Research Topic

Neuromuscular Training and Adaptations in Youth Athletes

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About this Research Topic

According to Myer and colleagues [1], neuromuscular training (NT) is a conceptual training model that is defined as a training program to incorporate general (e.g., fundamental movements) and specific (e.g., sport-specific movements) strength and conditioning activities, such as resistance, dynamic stability, core-focused strength, plyometric, and agility, that are designed to enhance health and skill-related components of physical fitness. Extensive literature emphasizes the positive effects of NT on muscular fitness and health in non-athletic youth. However, findings from NT studies in non-athletic youth were frequently translated to youth athletes which is not feasible because physiology and proficiency in motor performance differ markedly between non-athletic and athletic populations. Therefore, more research is needed on the impact of NT on muscular fitness (i.e., strength, power, endurance), athletic performance (i.e., proxies of performance in specific sport disciplines), and health-related outcomes (e.g., immune response, injury prevention) in youth athletes. Further, our knowledge with regards to the training-induced underlying physiological adaptive processes (neuro- and tendomuscular, immunological), following NT is limited.

Thus, the aims of this Frontiers Research Topic entitled "Neuromuscular Training and Adaptations in Youth Athletes" is to provide in depth knowledge in the form of original work, review articles, and meta-analyses on the effects of NT on muscular fitness, athletic performance, and injury prevention in youth athletes during the different stages of long-term athlete development.

We specifically ask interested authors to address the following research gaps that were recently identified in a scoping review published in Frontiers in Physiology [2]:

- Examine the effects of NT in child athletes
- Examine the effects of NT in female youth athletes
- Examine the relation between NT and health-related outcomes (e.g., orthopedic, immunological)
- Elucidate neuromuscular and tendomuscular mechanisms following NT in youth athletes according to sex and biological age

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KINGS-Studie

**KRAFTTRAINING IM
NACHWUCHSLEISTUNGSSPORT**

Publikationen - Artikel international

Behm, D.G., Young, J.D., Whitten, J.H.D., Reid, J.C., Quigley, P.J., Low, J., Li, Y., de Lima, C., Hodgson, D.D., Chaouachi, A., Prieske, O. & Granacher, U. (2017). Effectiveness of traditional strength versus power training on muscle strength, power and speed with youth: a systematic review and meta-analysis. *Frontiers in Physiology*, (Epub).

<http://journal.frontiersin.org/article/10.3389/fphys.2017.00423/full>

Numerous national associations and multiple reviews have documented the safety and efficacy of strength training for children and adolescents. The literature highlights the significant training-induced increases in strength associated with youth strength training. However, the effectiveness of youth strength training programs to improve power measures is not as clear. This discrepancy may be related to training and testing specificity. Most prior youth strength training programs emphasized lower intensity resistance with relatively slow movements. Since power activities typically involve higher intensity, explosive-like contractions with higher angular velocities (e.g., plyometrics), there is a conflict between the training medium and testing measures. This meta-analysis compared strength (e.g., training with resistance or body mass) and power training programs (e.g., plyometric training) on proxies of muscle strength, power, and speed. A systematic literature search using a Boolean Search Strategy was conducted in the electronic databases PubMed, SPORT Discus, Web of Science, and Google Scholar and revealed 652 hits. After perusal of title, abstract, and full text, 128 studies were eligible for inclusion in this systematic review and meta-analysis. The meta-analysis showed small to moderate magnitude changes for training specificity with jump measures. In other words, power training was more effective than strength training for improving youth jump height. For sprint measures, strength training was more effective than power training with youth. Furthermore, strength training exhibited consistently large magnitude changes to lower body strength measures, which contrasted with the generally trivial, small and moderate magnitude training improvements of power training upon lower body strength, sprint and jump measures, respectively.

Maturity related inadequacies in eccentric strength and balance might influence the lack of training specificity with the unilateral landings and propulsions associated with sprinting. Based on this meta-analysis, strength training should be incorporated prior to power training in order to establish an adequate foundation of strength for power training activities.

Keywords: Children, boys, girls, Plyometric training, Resistance Training

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Chaouachi, M., Granacher, U., Makhoulf, I., Hammami, R., Behm, D. G. & Chaouachi, A. (2017). Within Session Sequence of Balance and Plyometric Exercises Does Not Affect Training Adaptations with Youth Soccer Athletes. *Journal of Sports Science and Medicine*, 16, 125-136

<http://www.jssm.org/2jssm-16-125.xml>

The integration of balance and plyometric training has been shown to provide significant improvements in sprint, jump, agility, and other performance measures in young athletes. It is not known if a specific within session balance and plyometric exercise sequence provides more effective training adaptations. The objective of the present study was to investigate the effects of using a sequence of alternating pairs of exercises versus a block (series) of all balance exercises followed by a block of plyometric exercises on components of physical fitness such as muscle strength, power, speed, agility, and balance. Twenty-six male adolescent soccer players (13.9 ± 0.3 years) participated in an 8-week training program that either alternated individual balance (e.g., exercises on unstable surfaces) and plyometric (e.g., jumps, hops, rebounds) exercises or performed a block of balance exercises prior to a block of plyometric exercises within each training session. Pre- and post-training measures included proxies of strength, power, agility, sprint, and balance such as countermovement jumps, isometric back and knee extension strength, standing long jump, 10 and 30-m sprints, agility, standing stork, and Y-balance tests. Both groups exhibited significant, generally large magnitude (effect sizes) training improvements for all measures with mean performance increases of approximately >30%. There were no significant differences between the training groups over time. The results demonstrate the effectiveness of combining balance and plyometric exercises within a training session on components of physical fitness with young adolescents. The improved performance outcomes were not significantly influenced by the within session exercise sequence.

Keywords: Power; strength; jumps; sprints; balance; children

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Granacher, T., Goesele, A., Roggo, K., Wischer, T., Fischer, S., Zuerny, C., Gollhofer, A. & Kriemler, S. (2011). Effects and mechanisms of strength training in children. *International Journal of Sports Medicine*, 32(5), 357-364

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It has been demonstrated that strength training can be organized in children in a safe and effective way. However, there is limited data regarding its impact on muscle hypertrophy. This study investigated the effects of a high-intensity strength training (HIS) on knee extensor/flexor strength, countermovement (CMJ) jumping height, postural control, soft lean mass and muscle cross-sectional area (CSA) of the dominant leg in prepubertal children. Thirty-two children participated in this study and were assigned to an intervention (INT; N=17) or a control class (N=15). The INT participated in 10 weeks of weight-machine based HIS integrated in physical education. Pre/post tests included the measurements of peak torque of the knee extensors/flexors at 60 and 180°/s, CMJ jumping height, postural sway, soft lean mass of the leg by bioelectrical impedance analysis, and CSA (m. quadriceps) by magnetic resonance imaging. HIS resulted in significant increases in knee extensor/flexor peak torque (60°/s and 180°/s). HIS did not produce significant changes in CMJ jumping height, postural sway, soft lean mass, and CSA. Although HIS was effective at increasing peak torque of the knee extensors/flexors in children, it was unable to affect muscle size. It appears that neural factors rather than muscle hypertrophy account for the observed strength gains in children.

Keywords: resistance training; weight training; youth; muscle mass; peak torque; jumping height

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Granacher, U., Lesinski, M., Büsch, D., Muehlbauer, T., Prieske, O., Puta, C., Gollhofer, A. & Behm, D. G. (2016). Effects of resistance training in youth athletes on muscular fitness and athletic performance: a conceptual model for long-term athlete development. *Frontiers in Physiology*, 7, 164

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During the stages of long-term athlete development (LTAD), resistance training (RT) is an important means for (i) stimulating athletic development, (ii) tolerating the demands of long-term training and competition, and (iii) inducing long-term health promoting effects that are robust over time and track into adulthood. However, there is a gap in the literature with regards to optimal RT methods during LTAD and how RT is linked to biological age. Thus, the aims of this scoping review were (i) to describe and discuss the effects of RT on muscular fitness and athletic performance in youth athletes, (ii) to introduce a conceptual model on how to appropriately implement different types of RT within LTAD stages, and (iii) to identify research gaps from the existing literature by deducing implications for future research. In general, RT produced small-to-moderate effects on muscular fitness and athletic performance in youth athletes with muscular strength showing the largest improvement. Free weight, complex, and plyometric training appear to be well-suited to improve muscular fitness and athletic performance. In addition, balance training appears to be an important preparatory (facilitating) training program during all stages of LTAD but particularly during the early stages. As youth athletes become more mature, specificity, and intensity of RT methods increase. This scoping review identified research gaps that are summarized in the following and that should be addressed in future studies: (i) to elucidate the influence of gender and biological age on the adaptive potential following RT in youth athletes (especially in females), (ii) to describe RT protocols in more detail (i.e., always report stress and strain-based parameters), and (iii) to examine neuromuscular and tendomuscular adaptations following RT in youth athletes.

Keywords: weight lifting; children; adolescents; physical fitness; muscle strength; muscle power; muscular endurance

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Secular trends in strength and postural control have been reported for children and adolescents. Therefore, the objective of this study was to investigate the impact of a short-term ballistic strength training (BST) followed by detraining on measures of strength and postural control in adolescents. Twenty-eight high-school students participated in this study and were assigned to either an intervention ($n = 14$, age 16.7 ± 0.6 years, body mass index [BMI] $21.1 \pm 1.7 \text{ kg} \cdot \text{m}$) or a control group ($n = 14$, age 16.8 ± 0.7 years, BMI $19.9 \pm 1.7 \text{ kg} \cdot \text{m}$). The intervention class participated in a short-term (8 week) lower extremity BST program 2 times a week integrated in their regular physical education lessons. Pre, post, and follow-up tests included the measurements of maximal isometric force (MIF) and rate of force development (RFD) of the leg extensors on a leg press with the feet resting on a force platform, vertical jumping height (countermovement jump [CMJ]) on a force plate and the assessment of static (1-legged stance on a balance platform), and dynamic (mediolateral perturbation impulse on a balance platform) postural control. Ballistic strength training resulted in statistically significant improvements in MIF ($p = 0.001$) and CMJ height ($p < 0.001$), which were still present after detraining for MIF ($p = 0.04$). Furthermore, tendencies in terms of small to medium interaction effects yet not statistically significant improvements were found for RFD ($p = 0.38$), and measures of static ($p = 0.15$) but not of dynamic postural control. In adolescents, lower extremity BST is a suitable training modality for the application in a school setting (particularly during physical education lessons) that produced transient improvements in strength variables. These results could have an impact on improving the performance level in various motor fitness skills and sports activities in physical education.

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Granacher, U., Prieske, O., Majewski, M., Büsch, D. & Muehlbauer, T. (2015). The role of instability with plyometric training in sub-elite adolescent soccer players. *International Journal of Sports Medicine*, 36(5), 386-394

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The purpose of this study was to investigate the effects of plyometric training on stable (SPT) vs. highly unstable surfaces (IPT) on athletic performance in adolescent soccer players. 24 male sub-elite soccer players (age: 15±1 years) were assigned to 2 groups performing plyometric training for 8 weeks (2 sessions/week, 90 min each). The SPT group conducted plyometrics on stable and the IPT group on unstable surfaces. Tests included jump performance (countermovement jump [CMJ] height, drop jump [DJ] height, DJ performance index), sprint time, agility and balance. Statistical analysis revealed significant main effects of time for CMJ height ($p < 0.01$, $f = 1.44$), DJ height ($p < 0.01$, $f = 0.62$), DJ performance index ($p < 0.05$, $f = 0.60$), 0-10-m sprint time ($p < 0.05$, $f = 0.58$), agility ($p < 0.01$, $f = 1.15$) and balance ($p < 0.05$, $0.46 \leq f \leq 1.36$). Additionally, a Training group×Time interaction was found for CMJ height ($p < 0.01$, $f = 0.66$) in favor of the SPT group. Following 8 weeks of training, similar improvements in speed, agility and balance were observed in the IPT and SPT groups. However, the performance of IPT appears to be less effective for increasing CMJ height compared to SPT. It is thus recommended that coaches use SPT if the goal is to improve jump performance.

Keywords: strength; jump; speed; agility; balance

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Granacher, U., Schellbach, J., Klein, K., Prieske, O., Baeyens, J. P. & Muehlbauer, T. (2014). Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 6(1), 40

<http://www.biomedcentral.com/2052-1847/6/40>

Background:

It has been demonstrated that core strength training is an effective means to enhance trunk muscle strength (TMS) and proxies of physical fitness in youth. Of note, cross-sectional studies revealed that the inclusion of unstable elements in core strengthening exercises produced increases in trunk muscle activity and thus provide potential extra training stimuli for performance enhancement. Thus, utilizing unstable surfaces during core strength training may even produce larger performance gains. However, the effects of core strength training using unstable surfaces are unresolved in youth. This randomized controlled study specifically investigated the effects of core strength training performed on stable surfaces (CSTS) compared to unstable surfaces (CSTU) on physical fitness in school-aged children.

Methods:

Twenty-seven (14 girls, 13 boys) healthy subjects (mean age: 14 ± 1 years, age range: 13–15 years) were randomly assigned to a CSTS ($n=13$) or a CSTU ($n=14$) group. Both training programs lasted 6 weeks (2 sessions/week) and included frontal, dorsal, and lateral core exercises. During CSTU, these exercises were conducted on unstable surfaces (e.g., TOGU® DYN AIR CUSSIONS, THERA-BAND® STABILITY TRAINER).

Results:

Significant main effects of Time (pre vs. post) were observed for the TMS tests (8-22%, $f=0.47-0.76$), the jumping sideways test (4-5%, $f=1.07$), and the Y balance test (2-3%, $f=0.46-0.49$). Trends towards significance were found for the standing long jump test (1-3%, $f=0.39$) and the stand-and-reach test (0-2%, $f=0.39$). We could not detect any significant main effects of Group. Significant Time x Group interactions were detected for the stand-and-reach test in favour of the CSTU group (2%, $f=0.54$).

Conclusions:

Core strength training resulted in significant increases in proxies of physical fitness in adolescents. However, CSTU as compared to CSTS had only limited additional effects (i.e., stand-and-reach test). Consequently, if the goal of training is to enhance physical fitness, then CSTU has limited advantages over CSTS.

Keywords: Resistance training; Trunk; muscle strength; Physical fitness

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Hammami, R., Chaouachi, A., Makhlouf, I., Granacher, U. & Behm, D. G. (2016). Associations between balance and muscle strength, power performance in male youth athletes of different maturity status. *Pediatric Exercise Science*, 28(4), 521-534

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Balance, strength and power relationships may contain important information at various maturational stages to determine training priorities.

Purpose:

The objective was to examine maturity-specific relationships of static/dynamic balance with strength and power measures in young male athletes.

Methods:

Soccer players (N = 130) aged 10-16 were assessed with the Stork and Y balance (YBT) tests. Strength/power measures included back extensor muscle strength, standing long jump (SLJ), countermovement jump (CMJ), and 3-hop jump tests. Associations between balance with strength/power variables were calculated according to peak-height-velocity (PHV).

Results:

There were significant medium-large sized correlations between all balance measures with back extensor strength ($r = .486-.791$) and large associations with power ($r = .511-.827$). These correlation coefficients were significantly different between pre-PHV and circa PHV as well as pre-PHV and post-PHV with larger associations in the more mature groups. Irrespective of maturity-status, SLJ was the best strength/power predictor with the highest proportion of variance (12-47%) for balance (i.e., Stork eyes opened) and the YBT was the best balance predictor with the highest proportion of variance (43-78%) for all strength/power variables.

Conclusion:

The associations between balance and muscle strength/power measures in youth athletes that increase with maturity may imply transfer effects from balance to strength/power training and vice versa in youth athletes.

Keywords: adolescents; children; peak height velocity; relationships; training

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Hammami, R., Granacher, U., Makhlof, I., Behm, D. G. & Chaouachi, A. (2016). Sequencing effects of balance and plyometric training on physical performance in youth soccer athletes. *Journal of Strength and Conditioning Research*, 30(12), 3278-3289

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Balance training may have a preconditioning effect on subsequent power training with youth. There are no studies examining whether the sequencing of balance and plyometric training has additional training benefits. The objective was to examine the effect of sequencing balance and plyometric training on the performance of 12- to 13-year-old athletes. Twenty-four young elite soccer players trained twice per week for 8 weeks either with an initial 4 weeks of balance training followed by 4 weeks of plyometric training (BPT) or 4 weeks of plyometric training preceded by 4 weeks of balance training (PBT). Testing was conducted pre- and posttraining and included medicine ball throw; horizontal and vertical jumps; reactive strength; leg stiffness; agility; 10-, 20-, and 30-m sprints; Standing Stork balance test; and Y-Balance test. Results indicated that BPT provided significantly greater improvements with reactive strength index, absolute and relative leg stiffness, triple hop test, and a trend for the Y-Balance test ($p = 0.054$) compared with PBT. Although all other measures had similar changes for both groups, the average relative improvement for the BPT was 22.4% ($d = 1.5$) vs. 15.0% ($d = 1.1$) for the PBT. BPT effect sizes were greater with 8 of 13 measures. In conclusion, although either sequence of BPT or PBT improved jumping, hopping, sprint acceleration, and Standing Stork and Y-Balance, BPT initiated greater training improvements in reactive strength index, absolute and relative leg stiffness, triple hop test, and the Y-Balance test. BPT may provide either similar or superior performance enhancements compared with PBT.

Keywords: children; adolescents; power; jumps; sprints

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Kibele, A., Classen, C., Muehlbauer, T., Granacher, U. & Behm, D. G. (2014). Metastability in plyometric training on unstable surfaces: a pilot study. BMC Sports Science, Medicine and Rehabilitation, 6, 30

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Background:

In the past, plyometric training (PT) has been predominantly performed on stable surfaces. The purpose of this pilot study was to examine effects of a 7-week lower body PT on stable vs. unstable surfaces. This type of exercise condition may be denoted as metastable equilibrium.

Methods:

Thirty-three physically active male sport science students (age: 24.1 ± 3.8 years) were randomly assigned to a PT group ($n = 13$) exercising on stable (STAB) and a PT group ($n = 20$) on unstable surfaces (INST). Both groups trained counter-movement jumps, drop jumps, and practiced a hurdle jump course. In addition, high bar squats were performed. Physical fitness tests on stable surfaces (hexagonal obstacle test, countermovement jump, hurdle drop jump, left-right hop, dynamic and static balance tests, and leg extension strength) were used to examine the training effects.

Results:

Significant main effects of time (ANOVA) were found for the countermovement jump, hurdle drop jump, hexagonal test, dynamic balance, and leg extension strength. A significant interaction of time and training mode was detected for the countermovement jump in favor of the INST group. No significant improvements were evident for either group in the left-right hop and in the static balance test.

Conclusions:

These results show that lower body PT on unstable surfaces is a safe and efficient way to improve physical performance on stable surfaces.

Keywords: Balance training; Instability resistance training; Physical fitness test; Stretch-shortening cycle

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Legerlotz, K., Marzilger, R., Bohm, S. & Arampatzis, A. (2016). Physiological adaptations following resistance training in youth athletes – a narrative review. *Pediatric Exercise Science*, 28(4), 501-520

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Purpose:

To understand the mechanisms for the effects of resistance training on functional parameters, and to assess the injury risk of the involved tissues, it is necessary to examine the underlying morphological and structural changes of the respective tissues.

Methods:

The presented information on physiological adaptations have been deduced from cross-sectional studies comparing youth athletes with controls and children with adults as well as from longitudinal studies examining the effects of resistance training in untrained children and adolescents and in youth athletes.

Results:

The evidence indicates, that training induced changes in motor performance rely partly on enhanced neuromuscular control, and partly on morphological adaptation of muscles and tendons, such as changes in muscle, muscle fiber and tendon cross-sectional area, muscle composition, and tendon material properties, with the bone also adapting by increasing bone mineral content and cortical area.

Conclusion:

Although the training induced adaptations of the investigated tissues follows similar principles in children as in adults, the magnitude of the adaptive response appears to be more subtle. As studies investigating physiological adaptation in youth athletes are sparse, more research in this area is warranted to elucidate the specific physiological stimulus-response relationship necessary for effective training programs and injury prevention.

Keywords: strength training, neuronal adaptation, maturation, exercise performance

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Lesinski, M., Muehlbauer, T. & Granacher, U. (2016). Concurrent validity of the Gyko inertial sensor system for the assessment of vertical jump height in female sub-elite youth soccer players. *BMC Sports Science, Medicine and Rehabilitation*, 8: 35

<http://bmcsportsscimedrehabil.biomedcentral.com/articles/10.1186/s13102-016-0061-x>

Background:

The aim of the present study was to verify concurrent validity of the Gyko inertial sensor system for the assessment of vertical jump height.

Methods:

Nineteen female sub-elite youth soccer players (mean age: 14.7 ± 0.6 years) performed three trials of countermovement (CMJ) and squat jumps (SJ), respectively. Maximal vertical jump height was simultaneously quantified with the Gyko system, a Kistler force-plate (i.e., gold standard), and another criterion device that is frequently used in the field, the Optojump system.

Results:

Compared to the force-plate, the Gyko system determined significant systematic bias for mean CMJ (-0.66 cm, $p < 0.01$, $d = 1.41$) and mean SJ (-0.91 cm, $p < 0.01$, $d = 1.69$) height. Random bias was ± 3.2 cm for CMJ and ± 4.0 cm for SJ height and intraclass correlation coefficients (ICCs) were “excellent” (ICC = 0.87 for CMJ and 0.81 for SJ). Compared to the Optojump device, the Gyko system detected a significant systematic bias for mean CMJ (0.55 cm, $p < 0.05$, $d = 0.94$) but not for mean SJ (0.39 cm) height. Random bias was ± 3.3 cm for CMJ and ± 4.2 cm for SJ height and ICC values were “excellent” (ICC = 0.86 for CMJ and 0.82 for SJ).

Conclusion:

Consequently, apparatus specific regression equations were provided to estimate true vertical jump height for the Kistler force-plate and the Optojump device from Gyko-derived data. Our findings indicate that the Gyko system cannot be used interchangeably with a Kistler force-plate and the Optojump device in trained individuals.

It is suggested that practitioners apply the correction equations to estimate vertical jump height for the force-plate and the Optojump system from Gyko-derived data.

Keywords: Countermovement jump; Squat jump; Accelerometer; Lower-extremity; muscle power; Athlete; testing; Field test

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Lesinski, M., Prieske, O., Beurskens, R., Behm, D. G. & Granacher, U. (2016). Effects of drop height and surface instability on neuromuscular activation during drop jumps. *Scandinavian Journal of Medicine and Science in Sports*, epub ahead of print

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The purpose of this study was to examine whether drop height-induced changes in leg muscle activity during drop jumps (DJ) are additionally modulated by surface condition. Twenty-four healthy participants (23.7 ± 1.8 years) performed DJs on a force plate on stable, unstable, and highly unstable surfaces using different drop heights (i.e., 20 cm, 40 cm, 60 cm). Electromyographic (EMG) activity of soleus (SOL), gastrocnemius (GM), tibialis anterior (TA) muscles and coactivation of TA/SOL and TA/GM were analyzed for time intervals 100 ms prior to ground contact (preactivation) and 30-60 ms after ground contact [short latency response (SLR)]. Increasing drop heights resulted in progressively increased SOL and GM activity during preactivation and SLR ($P < 0.01$; $1.01 \leq d \leq 5.34$) while TA/SOL coactivation decreased ($P < 0.05$; $0.51 \leq d \leq 3.01$). Increasing surface instability produced decreased activities during preactivation (GM) and SLR (GM, SOL) ($P < 0.05$; $1.36 \leq d \leq 4.30$). Coactivation increased during SLR ($P < 0.05$; $1.50 \leq d \leq 2.58$). A significant drop height \times surface interaction was observed for SOL during SLR. Lower SOL activity was found on unstable compared to stable surfaces for drop heights ≥ 40 cm ($P < 0.05$; $1.25 \leq d \leq 2.12$). Findings revealed that instability-related changes in activity of selected leg muscles are minimally affected by drop height.

Keywords: EMG; Stretch-shortening cycle; preactivation; short latency response

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<http://www.ncbi.nlm.nih.gov/pubmed/26369626>

It has previously been shown that fatigue and unstable surfaces affect jump performance. However, the combination thereof is unresolved. Thus, the purpose of this study was to examine the effects of fatigue and surface instability on jump performance and leg muscle activity. Twenty elite volleyball players (18 ± 2 years) performed repetitive vertical double-leg box jumps until failure. Before and after a fatigue protocol, jump performance (i.e., jump height) and electromyographic activity of selected lower limb muscles were recorded during drop jumps (DJs) and countermovement jumps (CMJs) on a force plate on stable and unstable surfaces (i.e., balance pad on top of force plate). Jump performance (3-7%; $P < 0.05$; $1.14 \leq d \leq 2.82$), and muscle activity (2-27%; $P < 0.05$; $0.59 \leq d \leq 3.13$) were lower following fatigue during DJs and CMJs, and on unstable compared with stable surfaces during DJs only (jump performance: 8%; $P < 0.01$; $d = 1.90$; muscle activity: 9-25%; $P < 0.05$; $1.08 \leq d \leq 2.54$). No statistically significant interactions of fatigue by surface condition were observed. Our findings revealed that fatigue impairs neuromuscular performance during DJs and CMJs in elite volleyball players, whereas surface instability affects neuromuscular DJ performance only. Absent fatigue \times surface interactions indicate that fatigue-induced changes in jump performance are similar on stable and unstable surfaces in jump-trained athletes.

Keywords: EMG; Exhaustion; athlete; jump height; stretch-shortening cycle

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Lesinski, M., Prieske, O., & Granacher, U. (2016). Effects and dose–response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 50(13), 781–795

<http://bjsm.bmj.com/content/early/2016/02/05/bjsports-2015-095497.full.pdf+html>

Objectives:

To quantify age, sex, sport and training type-specific effects of resistance training on physical performance, and to characterise dose–response relationships of resistance training parameters that could maximise gains in physical performance in youth athletes.

Design:

Systematic review and meta-analysis of intervention studies.

Data sources:

Studies were identified by systematic literature search in the databases PubMed and Web of Science (1985–2015). Weighted mean standardised mean differences (SMD_w) were calculated using random-effects models.

Eligibility criteria for selecting studies:

Only studies with an active control group were included if these investigated the effects of resistance training in youth athletes (6–18 years) and tested at least one physical performance measure.

Results:

43 studies met the inclusion criteria. Our analyses revealed moderate effects of resistance training on muscle strength and vertical jump performance (SMD_w 0.8–1.09), and small effects on linear sprint, agility and sport-specific performance (SMD_w 0.58–0.75). Effects were moderated by sex and resistance training type. Independently computed dose–response relationships for resistance training parameters revealed that a training period of >23 weeks, 5 sets/exercise, 6–8 repetitions/set, a training intensity of 80–89% of 1 repetition maximum (RM), and 3–4 min rest between sets were most effective to improve muscle strength (SMD_w 2.09–3.40).

Summary/conclusions:

Resistance training is an effective method to enhance muscle strength and jump performance in youth athletes, moderated by sex and resistance training type. Dose–response relationships for key training parameters indicate that youth coaches should primarily implement resistance training programmes with fewer repetitions and higher intensities to improve physical performance measures of youth athletes.

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There is evidence that a non-uniform adaptation of muscle and tendon in young athletes results in increased tendon stress during mid-adolescence. The present longitudinal study investigated the development of the morphological and mechanical properties of muscle and tendon of volleyball athletes in a time period of 2 years from mid-adolescence to late adolescence. Eighteen elite volleyball athletes participated in magnetic resonance imaging and ultrasound-dynamometry sessions to determine quadriceps femoris muscle strength, vastus lateralis, medialis and intermedius morphology, and patellar tendon mechanical and morphological properties in mid-adolescence (16 ± 1 years) and late adolescence (18 ± 1 years). Muscle strength, anatomical cross-sectional area (CSA), and volume showed significant ($P < 0.05$) but moderate increases of 13%, 6%, and 6%, respectively. The increase of patellar tendon CSA ($P < 0.05$) was substantially greater (27%) and went in line with increased stiffness ($P < 0.05$; 25%) and reduced stress ($P < 0.05$; 9%). During late adolescence, a pronounced hypertrophy of the patellar tendon led to a mechanical strengthening of the tendon in relation to the functional and morphological development of the muscle. These adaptive processes may compensate the unfavorable relation of muscle strength and tendon loading capacity in mid-adolescence and might have implications on athletic performance and tendon injury risk.

Keywords: Muscle size; growth; imbalance; jumper's knee; knee joint; maturation; tendinopathy

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With the double stimulus of mechanical loading and maturation acting on the muscle-tendon unit, adolescent athletes might be at increased risk of developing imbalances of muscle strength and tendon mechanical properties. This longitudinal study aims to provide detailed information on how athletic training affects the time course of muscle-tendon adaptation during adolescence. In 12 adolescent elite athletes (A) and 8 similar-aged controls (C), knee extensor muscle strength and patellar tendon mechanical properties were measured over 1 yr in 3-mo intervals. A linear mixed-effects model was used to analyze time-dependent changes and the residuals of the model to quantify fluctuations over time. The cosine similarity (CS) served as a measure of uniformity of the relative changes of tendon force and stiffness. Muscle strength and tendon stiffness increased significantly in both groups ($P < 0.01$). However, the fluctuations of muscle strength were greater [A, 17 ± 7 (SD) N·m; C, 6 ± 2 N·m; $P < 0.05$] and the uniformity of changes of tendon force and stiffness was lower in athletes (CS A, -0.02 ± 0.5 ; C, 0.5 ± 0.4 ; $P < 0.05$). Further, athletes demonstrated greater maximum tendon strain (A, $7.6 \pm 1.7\%$; C, $5.5 \pm 0.9\%$; $P < 0.05$) and strain fluctuations (A, 0.9 ± 0.4 ; C, 0.3 ± 0.1 ; $P < 0.05$). We conclude that athletic training in adolescence affects the uniformity of muscle and tendon adaptation, which increases the demand on the tendon with potential implications for tendon injury.

Keywords: adolescence; biomechanics; knee; plasticity; tendinopathy; time course

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Mersmann, F., Charcharis, G., Bohm, S. & Adamantios, A. (2017). Muscle and tendon adaptation in adolescence: Elite volleyball athletes compared to untrained boys and girls. *Frontiers in Physiology*.

<http://journal.frontiersin.org/article/10.3389/fphys.2017.00417/abstract>

Though the plasticity of human tendons is well explored in adults, it is still unknown how superimposed mechanical loading by means of athletic training affects the properties of tendons during maturation. Due to the increased responsiveness of muscle to mechanical loading, adolescence is an important phase to investigate the effects of training on the mechanical properties of tendons. Hence, in the present study we compared vastus lateralis (VL) architecture, muscle strength of the knee extensor muscles and patellar tendon mechanical properties of male and female adolescent elite athletes to untrained boys and girls.

Twenty-one adolescent volleyball athletes (A; 16.7±1 years; 12 boys, 9 girls) and 24 similar-aged controls (C; 16.7±1 years; 12 boys and girls, respectively) performed maximum isometric contractions on a dynamometer for the assessment of muscle strength and, by integrating ultrasound imaging, patellar tendon mechanical properties. Respective joint moments were calculated using an inverse dynamics approach and an electromyography-based estimation of antagonistic contribution. Additionally, the VL pennation angle, fascicle length and muscle-thickness were determined in the inactive state by means of ultrasound.

Adolescent athletes produced significantly greater knee extension moments (normalized to body mass) compared to controls (A: 4.23 ± 0.80 Nm/kg, C: 3.57 ± 0.67 Nm/kg; $p = 0.004$), and showed greater VL thickness and pennation angle (+38% and +27%; $p < 0.001$).

Tendon stiffness (normalized to rest length) was also significantly higher in athletes (A: 86.0 ± 27.1 kN/strain, C: 70.2 ± 18.8 kN/strain; $p = 0.04$), yet less pronounced compared to tendon force (A: 5785 ± 1146 N, C: 4335 ± 1015 N; $p < 0.001$), which resulted in higher levels of tendon strain during maximum contractions in athletes (A: 8.0 ± 1.9%, C: 6.4 ± 1.8%; $p = 0.008$).

We conclude that athletic volleyball training provides a more efficient stimulus for muscle compared to tendon adaptation, which results in an increased demand placed upon the tendon by the working muscle in adolescent volleyball athletes. Besides implications for sport performance, these findings might have important consequences for the risk of tendon overuse injury.

Keywords: Muscle; Tendon; adaptation; Athletes; adolescence; Tendinopathy; Imbalance

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Muehlbauer, T., Granacher, U. & Gollhofer, A. (2012). Sex-related effects in strength training during adolescence: a pilot study. *Perceptual & Motor Skills*, 115(3), 953-968

<http://www.ncbi.nlm.nih.gov/pubmed/23409607>

The objective was to investigate the effects of high-velocity strength training on isometric strength of the leg extensors and jump height in female and male adolescents. Twenty-eight students (13 boys, 15 girls) ages 16 to 17 years participated in this study and were assigned to either a strength training group or a control group. Strength training was conducted over 8 weeks (2 times per week). Pre- and post-training tests included the measurements of maximal isometric force and rate of force development of the leg extensors as well as countermovement jump height. Both girls (effect size = 1.37) and boys (effect size = 0.61) showed significant improvements in jump height. However, significant increases in maximal isometric force (effect size = 1.85) and rate of force development (effect size = 2.23) were found only in girls. In female and male adolescents, high-velocity strength training is an effective training regimen that produced improvements in countermovement jump height in both sexes but higher gains in maximal isometric force and rate of force development in girls.

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<http://www.ncbi.nlm.nih.gov/pubmed/27548781>

The primary purpose of this study was to examine concurrent validity of the jump-and-reach (JaR) test using the Vertec system and a criterion device (i.e., Optojump system). In separate subanalyses, we investigated the influence of gym floor condition and athletes' sex on the validity of vertical jump height. Four hundred forty subelite adolescent female ($n = 222$, mean age: 14 ± 1 year, age range: 13-15 years) and male ($n = 218$, mean age: 15 ± 1 year, age range: 14-16 years) handball players performed the JaR test in gyms with region or point elastic floors. Maximal vertical jump height was simultaneously assessed using the Vertec and the Optojump systems. In general, significantly higher jump heights were obtained for the Vertec compared with the Optojump system (11.2 cm, $\Delta 31\%$, Cohen's $d = 2.58$). The subanalyses revealed significantly larger jump heights for the Vertec compared with the Optojump system irrespective of gym floor condition and players' sex. The association between Optojump- and Vertec-derived vertical jump heights amounted to $r_P = 0.84$, with a coefficient of determination (R) of 0.71. The subanalyses indicated significantly larger correlations in males ($r_P = 0.75$, $R = 0.56$) than in females ($r_P = 0.63$, $R = 0.40$). Yet, correlations were not significantly different between region ($r_P = 0.83$, $R = 0.69$) as opposed to point elastic floor ($r_P = 0.87$, $R = 0.76$). Our findings indicate that the 2 apparatuses cannot be used interchangeably. Consequently, gym floor and sex-specific regression equations were provided to estimate true (Optojump system) vertical jump height from Vertec-derived data.

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<http://www.ncbi.nlm.nih.gov/pubmed/27050241>

The aim of this study was to assess the effectiveness of a 12-week in-season low-to-moderate load high-velocity resistance training (HVRT) in addition to soccer training as compared with soccer training only on proxies of athletic performance in prepubertal soccer players. Twenty-four male soccer players performed 2 different protocols: (a) regular soccer training with 5 sessions per week ($n = 11$; age = 12.7 ± 0.3 years) and (b) regular soccer training with 3 sessions per week and HVRT with 2 sessions per week ($n = 13$; age = 12.8 ± 0.2 years). The outcome measures included tests for the assessment of muscle strength (e.g., 1 repetition maximum [1RM] half-squat tests), jump ability (e.g., countermovement jump, squat jump [SJ], standing long jump [SLJ]), and multiple 5-bound tests [MB5s]), linear speed (e.g., 5-, 10-, 20-, and 30-m sprint tests), and change of direction (e.g., T-test and Illinois change of direction test). Results revealed significant group \times test interactions for the SJ test ($p \leq 0.05$, $d = 0.59$) and the SLJ test ($p < 0.01$, $d = 0.83$). Post hoc tests illustrated significant pre-post changes in the HVRT group (SJ: [INCREMENT]22%, $p < 0.001$, $d = 1.26$; SLJ: [INCREMENT]15%, $p < 0.001$, $d = 1.30$) but not in the control group. In addition, tendencies toward significant interaction effects were found for the 1RM half-squat ($p = 0.08$, $d = 0.54$) and the 10-m sprint test ($p = 0.06$, $d = 0.57$). Significant pre-post changes were found for both parameters in the HVRT group only (1RM: [INCREMENT]25%, $p < 0.001$, $d = 1.23$; 10-m sprint: [INCREMENT]7%, $p < 0.0001$, $d = 1.47$). In summary, in-season low-to-moderate load HVRT conducted in combination with regular soccer training is a safe and feasible intervention that has positive effects on maximal strength, vertical and horizontal jump and sprint performance as compared with soccer training only.

Keywords: youth soccer; change of direction; jump performances; sprint

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Negra, Y., Chaabene, H., Sammoud, S., Bouguezzi, R., Abbes, M.A. & Granacher, U. (2017). Effects of plyometric training on physical fitness in prepuberal soccer athletes. *International Journal of Sports Medicine*, (Epub).

<https://www.thieme-connect.de/products/ejournals/pdf/10.1055/s-0042-122337.pdf>

This study aimed at examining the effects of plyometric training on stable (SPT) vs. unstable (UPT) surfaces on physical fitness in prepuberal soccer players. Male athletes were randomly assigned to SPT ($n=18$; age= 12.7 ± 0.2 years) or UPT ($n=16$; age= 12.2 ± 0.5 years). Both groups conducted 3 regular soccer training sessions per week combined with either 2 SPT or UPT sessions. Assessment of jumping ability (countermovement jump [CMJ]), and standing long jump [SLJ]), speed (10-m, 20-m, 30-m sprint), agility (Illinois agility test [IAT]), and balance (stable [SSBT], unstable [USBT] stork balance test; stable [SYBT], unstable [UYBT] Y balance test) was conducted pre-and post-training. An ANCOVA model was used to test for between-group differences (SPT vs. UPT) at post-test using baseline values as covariates. No significant differences were found for CMJ height ($p>0.05$, $d=0.54$), SLJ ($p>0.05$; $d=0.81$), 10-m, 20-m, and 30-m sprint performances ($p>0.05$, $d=0.00-0.24$), IAT ($p>0.05$, $d=0.48$), and dynamic balance (SYBT and UYBT, both $p>0.05$, $d=0.39$, 0.08 , respectively). Statistically significant between-group differences were detected for the USBT ($p<0.01$, $d=1.86$) and the SSBT ($p<0.01$, $d=1.75$) in favor of UPT. Following 8 weeks of SPT or UPT in prepuberal athletes, similar performance levels were observed in both groups for measures of jumping ability, speed, dynamic balance, and agility. However, if the goal is to additionally enhance static balance, UPT has an advantage over SPT.

Keywords: Youth; balance; jumping ability; athletic performance; football

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Prieske, O., Muehlbauer, T., Borde, R., Gube, M., Bruhn, S., Behm, D. G. & Granacher, U. (2016). Neuromuscular and athletic performance following core strength training in elite youth soccer: role of instability. *Scandinavian Journal of Medicine and Science in Sports*, 26(1), 48-56

<http://www.ncbi.nlm.nih.gov/pubmed/25559249>

Cross-sectional studies revealed that inclusion of unstable elements in core-strengthening exercises produced increases in trunk muscle activity and thus potential extra stimuli to induce more pronounced performance enhancements in youth athletes. Thus, the purpose of the study was to investigate changes in neuromuscular and athletic performance following core strength training performed on unstable (CSTU) compared with stable surfaces (CSTS) in youth soccer players. Thirty-nine male elite soccer players (age: 17 ± 1 years) were assigned to two groups performing a progressive core strength-training program for 9 weeks (2-3 times/week) in addition to regular in-season soccer training. CSTS group conducted core exercises on stable (i.e., floor, bench) and CSTU group on unstable (e.g., Thera-Band® Stability Trainer, Togu© Swiss ball) surfaces. Measurements included tests for assessing trunk muscle strength/activation, countermovement jump height, sprint time, agility time, and kicking performance. Statistical analysis revealed significant main effects of test (pre vs post) for trunk extensor strength (5%, $P < 0.05$, $d = 0.86$), 10-20-m sprint time (3%, $P < 0.05$, $d = 2.56$), and kicking performance (1%, $P < 0.01$, $d = 1.28$). No significant Group \times test interactions were observed for any variable. In conclusion, trunk muscle strength, sprint, and kicking performance improved following CSTU and CSTS when conducted in combination with regular soccer training.

Keywords: Elite sports; agility; ball speed; electromyography; jumping; sprint

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Prieske, O., Muehlbauer, T. & Granacher, U. (2015). The role of trunk muscle strength for physical fitness and athletic performance in trained individuals: a systematic review and meta-analysis. *Sports Medicine*, 46(3), 401-419

<http://www.ncbi.nlm.nih.gov/pubmed/26589515>

Background:

The importance of trunk muscle strength (TMS) for physical fitness and athletic performance has been demonstrated by studies reporting significant correlations between those capacities. However, evidence-based knowledge regarding the magnitude of correlations between TMS and proxies of physical fitness and athletic performance as well as potential effects of core strength training (CST) on TMS, physical fitness and athletic performance variables is currently lacking for trained individuals.

Objective:

The aims of this systematic review and meta-analysis were to quantify associations between variables of TMS, physical fitness and athletic performance and effects of CST on these measures in healthy trained individuals.

Data Sources:

PubMed, Web of Science, and SPORTDiscus were systematically screened from January 1984 to March 2015.

Study Eligibility Criteria:

Studies were included that investigated healthy trained individuals aged 16-44 years and tested at least one measure of TMS, muscle strength, muscle power, balance, and/or athletic performance.

Study Appraisal and Synthesis Methods:

Z-transformed Pearson's correlation coefficients between measures of TMS and physical performance were aggregated and back-transformed to r values. Further, to quantify the effects of CST, weighted standardized mean differences (SMDs) of TMS and physical performance were calculated using random effects models. The methodological quality of CST studies was assessed by the Physiotherapy Evidence Database (PEDro) scale.

Results:

Small-sized relationships of TMS with physical performance measures ($-0.05 \leq r \leq 0.18$) were found in 15 correlation studies. Sixteen intervention studies revealed large effects of CST on measures of TMS ($SMD = 1.07$) but small-to-medium-sized effects on proxies of physical performance ($0 \leq SMD \leq 0.71$) compared with no training or regular training only. The methodological quality of CST studies was low (median PEDro score = 4).

Conclusions:

Our findings indicate that TMS plays only a minor role for physical fitness and athletic performance in trained individuals. In fact, CST appears to be an effective means to increase TMS and was associated with only limited gains in physical fitness and athletic performance measures when compared with no or only regular training.

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KINGS-Studie

**KRAFTTRAINING IM
NACHWUCHSLEISTUNGSSPORT**

Publikationen - Artikel national

Boeth, H., Morgenstern, C., Pourat, D., Krahl, L., Köhnecke, F., Schlausch, S., Jung, T., Perka, C. & Duda, G. N. (2016). Kniegelenkstabilisierungstraining. Leistungssport, 46(6), 33-36.

<https://leistungssport.net/aktuelle-ausgabe/>

Kniegelenksverletzungen und Überlastungsschäden nehmen im Nachwuchsleistungssport deutlich zu. Zur Vorbeugung solcher Verletzungen ist die Kniestabilität zu erhöhen. Ausgehend von einer Erfassung der individuellen Gelenkstabilität wurde eine individuell angepasste Trainingsintervention entwickelt mit dem Ziel, muskuläre Dysbalancen zu kompensieren und die Kniegelenkstabilität zu erhöhen.

Keywords: Krafttraining; Nachwuchsleistungssport;Kniegelenkverletzung en; Kniegelenkstabilität

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Brown, N., Schlechtweg, S. & Alt, W. (2016). Automatisiertes Krafttrainingsmonitoring: Möglichkeiten zur objektiven Protokollierung und Steuerung von Belastung und Beanspruchung. Leistungssport, 46(6), 27-28

<https://leistungssport.net/aktuelle-ausgabe/>

Mit einer speziellen App können neben Belastungs- auch Beanspruchungsparameter protokolliert werden, womit eine umfassende Quantifizierung des Trainings ermöglicht wird. Dadurch werden Athleten und Trainer bei der Gestaltung des Trainings, der Analyse von Saisonverläufen und der Trainingssteuerung bestmöglich unterstützt.

Keywords: Krafttraining; Belastung; Beanspruchung; Trainingsdatendokumentation

Büsch, D., Marschall, F., Arampatzis, A. & Granacher, U. (2016). Reaktivkrafttraining im Nachwuchsleistungssport: Trainingspraktische Empfehlungen für den langfristigen Leistungsaufbau im Handball. Leistungssport, 46(6), 23-26

<https://leistungssport.net/aktuelle-ausgabe/>

Reaktivkrafttraining stellt eine besonders effektive Trainingsform dar, um sportartspezifische Leistungen zu verbessern, Sportverletzungen zu vermeiden oder nach einer Sportverletzung möglichst schnell wieder einsetzbar zu sein. Die Belastungsgrößen und ergänzenden Trainingsmaßnahmen für ein effektives und verletzungs vorbeugendes Reaktivkrafttraining werden beschrieben und kurz begründet.

Keywords: Krafttraining; Nachwuchsleistungssport; Reaktivkraft

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Büsch, D., Marschall, F., Goebe, R., Krome, A. & Granacher, U. (2016). Differenziertes Reaktivkrafttraining für Handballer. Handballtraining, 38(12), 38-48

https://philippka.de/shop/handball/handball-zeitschriften/handball-training.html#/21-abo_laufzeit-unbefristet/24-land-versand_innerhalb_deutschlands/280-pramie-10_euro_gutschein_fur_den_philippka_shop/293-geschenkgutschein-nicht_moglich/263-bezug_ab-12_2016_dezember

Büsch, D., Marschall, F., Goebel, R., Kromer, A. & Granacher, U. (2016). Differenziertes Reaktivkrafttraining für Handballer. Teil 1. Handballtraining, 38 (12), 38–41

Dass Tobias Reichmann vom Boden abhebt, als habe er Sprungfedern unter den Füßen, oder die Rückraumkracher von Mikkel Hansen den Anschein erwecken, als seien sie von einem Katapult abgefeuert, hat einen Grund: Die enorme Beschleunigung resultiert aus der sogenannten Reaktivkraft. Wie eine Sprungfeder erst zusammengedrückt (oder ein Katapult gespannt) wird, um eine explosive Gegenbewegung auszulösen, so macht sich – vereinfacht ausgedrückt – die Reaktivkraft die bei der Ausholbewegung gespeicherte Energie zunutze. Der erste Beitragsteil erläutert die grundlegenden Zusammenhänge eines Reaktivkrafttrainings und vermittelt wichtige Trainingseitsätze und Belastungsempfehlungen. Die Darstellung entsprechender Trainingsformen zur Verbesserung von Sprung- und Wurfkraft wird in den folgenden Beitragsteilen fortgesetzt.

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Büsch, D., Marschall, F., Goebel, R., Kromer, A. & Granacher, U. (2017). Differenziertes Reaktivkrafttraining für Handballer. Teil 2. Handballtraining, 39 (1), 6–19

Die wesentlichen theoretischen Grundlagen des Reaktivkrafttrainings sind im ersten Beitragsteil vermittelt worden. Neben ersten Praxisbeispielen enthielt dieser darüber hinaus Leitsätze für Athletinnen und Athleten sowie Trainerinnen und Trainer, die – im Sinne einer effektiven und verletzungsvermeidenden Durchführung – bei der Umsetzung entsprechender Trainingsformen unbedingt zu berücksichtigen sind. Teil 2 stellt sechzehn weitere Übungen für die unteren bzw. oberen Extremitäten vor, die den Intensitätsstufen gering, mittel oder hoch zugeordnet sind.

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Büsch, D., Pabst, J., Mühlbauer, T., Ehrhardt, P. & Granacher, U. (2015). Effekte plyometrischen Trainings unter Verwendung instabiler Untergründe auf sportmotorische Sprung- und Schnelligkeitsleistungen von Nachwuchsleistungshandballern. *Sport-Orthopädie - Sport-Traumatologie*, 31(4), 299-308

<http://www.sciencedirect.com/science/article/pii/S0949328X15001532>

Einleitung:

Sprungleistungen stellen einen leistungsdeterminierenden Faktor für den Wettkampferfolg im Handball dar. Zur Ausschöpfung dieser Leistungsreserve wurde bislang vorwiegend plyometrisches Training auf stabilen Untergründen durchgeführt. Tacklings von Gegenspielern führen oftmals zu Störungen im Bewegungsablauf und damit zu Bewegungsausführungen unter initial instabilen Ausgangsbedingungen, sodass es das Ziel der vorliegenden Studie war, die Effekte eines plyometrischen Trainings auf stabilen versus instabilen Untergründen, auf Sprung- und Schnelligkeitsleistungen bei Nachwuchsleistungshandballern zu überprüfen.

Methode:

An der Studie nahmen 19 Nachwuchsleistungshandballer (D/C-Kader) im Alter von 16-18 Jahren teil, die randomisiert in eine stabile (STAB) und eine instabile (INSTAB) plyometrische Trainingsgruppe eingeteilt wurden. Zur Überprüfung der Trainingseffekte wurden vor und nach der Trainingsphase Sprungleistungen (Nieder-Hoch-Sprünge [DJ], Sprünge mit Ausholbewegung [CMJ], Sprünge ohne Ausholbewegung [SJ]), der Standweitsprung und unterschiedliche Sprintleistungen (20-m-Sprint und Achterlauf) erfasst.

Ergebnisse:

Im Ergebnis der Varianzanalyse zeigten sich signifikante Haupteffekte für den Faktor Zeit beim CMJ und SJ ($p \leq 0,004$, $1,63 \leq d \leq 2,04$) sowie signifikante Haupteffekte für den Faktor Zeit bei den linearen 10- und 20-m-Schnelligkeitsleistungen ($p \leq 0,006$, $1,53 \leq d \leq 1,59$).

Schlussfolgerung:

Das plyometrische Training führte bei beiden Gruppen zu signifikanten Steigerungen in den Sprung- und Schnelligkeitsleistungen. Allerdings konnten keine zusätzlich leistungssteigernden Effekte des plyometrischen Trainings mit instabilen Untergründen ermittelt werden. Basierend auf den vorliegenden Ergebnissen wird ein plyometrisches Training auf stabilen Untergründen zur Steigerung der Vertikalsprung- und Sprintleistung empfohlen.

Keywords: Sprungkrafttraining; Belastungsgefüge; sportliche Leistung; Spitzensport

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Gabriel, H., Puta, C., Arampatzis, A. & Granacher, U. (2016). Fazit und Ausblick der KINGS-Studie: Potenziale des Nachwuchsleistungssports für junge Menschen. *Leistungssport*, 46(6), 37-39

<https://leistungssport.net/aktuelle-ausgabe/>

Leistung – Leiblichkeit – Literacy – Lebensziele – Lebensführung. Gerade Kinder und Jugendliche durchlaufen eine dynamische Entwicklung mit Veränderung der eigenen Lebensziele. Vor dem Hintergrund ihrer eigenen Lebenserfahrungen haben junge Menschen Lebensziele. Hinzu kommen die Erfahrungen des Trainings- und Wettkampfprozesses, die zu einer immer wieder neuen Wahrnehmung der eigenen Leiblichkeit führen. Der Beitrag des Nachwuchsleistungssports ist der körperliche Bildungs- und Reflexionsprozess („physical literacy“), der die zunehmende Übernahme der Verantwortung für das eigene Leben in dem sozialen Umfeld und der Gesellschaft führen kann und soll. Die andauernde und dynamische Entwicklung des Wahrnehmungs-, Bildungs- und Reflexionsprozesses im leistungssportlichen Umfeld nimmt Einfluss auf die Lebensführung der jungen Menschen. Diese individuelle subjektbezogene Auswirkung hat Bedeutung für die Person selbst, das Umfeld und die Öffentlichkeit.

Keywords: Krafttraining; Nachwuchsleistungssport; Perspektive, subjektive

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Granacher, U., Arampatzis, A. & Gabriel, H. (2016). Gesunde Spitzenleistung – für Deutschland und sich selbst. Leistungssport, 46(6), 10

<https://leistungssport.net/aktuelle-ausgabe/>

Correspondence: Prof. Urs Granacher, University of Potsdam
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Granacher, U. (2015). WVL-Projekt Krafttraining im Nachwuchsleistungssport (KINGS-Studie): wissenschaftlich fundierte Empfehlungen für die Praxis. Leistungssport, 45(2), 36-38

http://leistungssport.net/jahresuebersicht/detail/news/leistungssport-22015/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=1697545bd244f5d3b48132daf9debf20

Aktuelle Analysen zeigen, dass wesentliche Forschungsgrundlagen bezüglich alters-, geschlechts- und sportartspezifischer Belastungsnormative, der Inhalte der Krafttrainingsmaßnahmen sowie der Validierung und Weiter-/Neuentwicklung von Kraftmessverfahren im Feld fehlen. In den kommenden Jahren wird ein interdisziplinäres wissenschaftliches Projektteam in Kooperation mit leistungssportrelevanten außeruniversitären Projektpartnern dieses Forschungsdefizit aufarbeiten und die Übertragung der wissenschaftlichen Erkenntnisse in die Praxis vorantreiben.

Keywords: Nachwuchsleistungssport; Krafttraining

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Granacher, U. et al. (2015). Mehr als Hanteln, Schweiß und Muskelberge. Verbundprojekt forscht zum Krafttraining im Nachwuchsleistungssport. Portal Wissen, 2, 32-36

[Portal Wissen_Juli_2015.pdf](#)

Krafttraining galt lange als Zeitvertreib für Enthusiasten. Ihr Ziel: Kraft steigern und Muskelmasse aufbauen. Inzwischen weiß man, dass systematisch geplantes, strukturiertes und dosiertes Krafttraining nicht nur die Muskulatur stärkt sondern tatsächlich körperlich fit und gesund macht. Es kräftigt die Muskulatur, verbessert sport- und alltagsmotorische Leistungen, reduziert Verletzungsrisiken und wirkt positiv bei Volkskrankheiten wie Rückenschmerzen, Diabetes und Adipositas. Leistungssportler wiederum können mittels Krafttraining ihre allgemeine motorische Leistung - wie Sprungkraft, Schnelligkeit und Gewandtheit - , aber auch sportartspezifische Leistungen - etwa die Torschuss- oder Aufschlaggeschwindigkeit - verbessern. Umstritten war indes bis in die 1990er Jahre, ob auch Kinder und Jugendliche von Krafttraining profitieren können oder hier nicht vielmehr gesundheitliche Risiken zu befürchten sind. Ein Verbundprojekt der Universität Potsdam mit Partnern aus Wissenschaft und Praxis soll nun die Wirksamkeit von „Krafttraining im Nachwuchsleistungssport (KINGS)“ nachweisen - und daraus konkrete Empfehlungen für die Trainingspraxis ableiten. Gefördert wird das Kooperationsvorhaben im wissenschaftlichen Verbundsystem Leistungssport (WVL) durch das Bundesinstitut für Sportwissenschaft (BISp).

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Granacher, U., Kriemler, S., Gollhofer, A. & Zahner, L. (2009). Neuromuskuläre Auswirkungen von Krafttraining im Kindes- und Jugendalter: Hinweise für die Trainingspraxis. *Deutsche Zeitschrift für Sportmedizin*, 60(2), 41-49

<http://www.zeitschrift-sportmedizin.de/artikel-online/archiv-2009/heft-2/neuromuskulaere-auswirkungen-von-krafttraining-im-kindes-und-jugendalter/>

The attitude towards resistance or strength training in children and adolescents has changed throughout the last couple of years due to international research efforts. Today, resistance training has proved to be a safe and effective regimen to increase strength performance, to enhance bone density, and to prevent injuries in youth sports and recreational activities. However, only little research has been done in German-speaking countries. On the basis of the relevant literature, this review deals with the neuromuscular impact of resistance training in children and adolescents as well as with the resultant implications for exercise. The findings of this review imply that resistance training protocols for grown-ups cannot directly be applied for the needs of children and adolescents. Differences in the physiological condition of children and grown-ups seem to be responsible for this phenomenon, which again cause divergent training-related neuromuscular adaptations. As a consequence, age-specific planning of resistance training protocols is mandatory.

Keywords: children, adolescents, strength training, neuromuscular performance

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Hoffmann, A., Kaminsky, T., Neumann, T. & Adermann, C. (2016). Individuelle Entwicklungsdokumentation: Praktischer Nutzen und Einsatzmöglichkeiten. *Leistungssport*, 46(6), 29-32

<https://leistungssport.net/aktuelle-ausgabe/>

Im Rahmen der KINGS-Studie wurde die Datenbank IED (individuelle Entwicklungsdatenbank) weiterentwickelt. Dadurch wird für den Athleten die komplexe Analyse von Leistungs-, Trainings- und Wettkampfdaten seiner sportlichen Entwicklung vom Talent bis zur Spitze möglich.

Keywords: Nachwuchsleistungssport; Leistungsaufbau, langfristiger; Entwicklung; Trainingsdatendokumentation

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Lesinski, M., Muehlbauer, T., Büsch, D. & Granacher, U. (2014). Effekte von Komplextraining auf Kraft- und Schnellkeitsleistungen bei Sportlern: Ein systematischer Überblick. *Sportverletzung Sportschaden*, 28(2), 85-107

<https://www.thieme-connect.com/products/ejournals//10.1055/s-0034-1366145>

Background:

Post-activation potentiation (PAP) can elicit acute performance enhancements in variables of strength, power, and speed. However, it is unresolved whether the frequent integration of PAP eliciting conditioning activities in training (i.e., complex training) results in long-term adaptations. In this regard, it is of interest to know whether complex training results in larger performance enhancements as compared to more traditional and isolated training regimens (e.g., resistance training). Thus, this systematic literature review summarises the current state of the art regarding the effects of complex training on measures of strength, power, and speed in recreational, subelite, and elite athletes. Further, it provides information on training volume and intensities that proved to be effective.

Methods:

Our literature search included the electronic databases Pubmed, SportDiscus, and Web of Science (1995 to September 2013). In total, 17 studies met the inclusionary criteria for review. Ten studies examined alternating complex training and 7 studies sequenced complex training.

Results:

Our findings indicated small to large effects for both alternating complex training (countermovement jump height: +7.4% [ESd=-0.43]; squat jump height: +9.8% [ESd=-0.66]; sprint time: -2.4% [ESd=0.63]) and sequenced complex training (countermovement jump height: +6.0% [ESd=-0.83]; squat jump height: +11.9% [ESd=-0.97], sprint time: -0.7% [ESd=0.52]) in measures of power and speed. As compared to more traditional training regimens, alternating and sequenced complex training showed only small effects in measures of strength, power, and speed. A more detailed analysis of alternating complex training revealed larger effects in countermovement jump height in recreational athletes (+9.7% [ESd=-0.57]) as compared to subelite and elite athletes (+2.7% [ESd=-0.15]).

Based on the relevant and currently available literature, missing data (e.g., time for rest interval) and diverse information regarding training volume and intensity do not allow us to establish evidence-based dose-response relations for complex training.

Conclusion:

Complex training represents an effective training regimen for athletes if the goal is to enhance strength, power, and speed. Studies with high methodological quality have to be conducted in the future to elucidate whether complex training is less, similar, or even more effective compared to more traditional training regimens. Finally, it should be clarified whether alternated and/or sequenced conditioning activities implemented in complex training actually elicit acute PAP effects.

Keywords: resistance training ; plyometric training ; dose; response relation ; athletic performance ; elite sport

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Lesinski, M., Mühlbauer, T., Prieske, O., Büsch, D., Gollhofer, A., Puta, C., Behm, D. G. & Granacher, U. (2016). Krafttraining im Nachwuchsleistungssport: Wirkungen und Einsatz im langfristigen Leistungsaufbau. *Leistungssport*, 46(6), 11-14

<https://leistungssport.net/aktuelle-ausgabe/>

Dieser Beitrag informiert über die generellen sowie alters-, geschlechts- und trainingsformspezifischen Wirkungen von Krafttraining auf die Maximal-/Schnellkraft, die Kraftausdauer sowie auf sportartspezifische Leistungen von Nachwuchsathleten. Zudem wird ein Modell zur Implementierung verschiedener Krafttrainingsformen in den langfristigen Leistungsaufbau vorgestellt.

Keywords: Krafttraining; Nachwuchsleistungssport; Leistungsaufbau, langfristiger

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Mersmann, F., Bohm, S. & Arampatzis, A. (2016). Dysbalancen der Muskel- und Sehnenadaptation: Notwendigkeit eines spezifischen Sehnentrainings im (Nachwuchs-)Leistungssport. *Leistungssport*, 46(6), 19-22

<https://leistungssport.net/aktuelle-ausgabe/>

Der Beitrag fasst den gegenwärtigen Kenntnisstand zum Anpassungsverhalten von Muskel und Sehne mit Schwerpunkt auf eigenen Forschungsergebnissen zu Dysbalancen bei jugendlichen Athleten sowie zur training-sinduzierten Adaptation der Sehne zusammen. Daraus werden praktische Folgerungen abgeleitet, wie Dysbalancen in der Entwicklung von Sehnen und Muskeln vorgebeugt werden kann.

Keywords: Krafttraining; Nachwuchsleistungssport; Muskel-/Sehnenadaptation; Dysbalancen

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Prieske, O., Lesinski, M., Kriemler, S. & Granacher, U. (2016). Krafttraining im Kindes- und Jugendalter: Wirkungen, Anpassungsmechanismen und Empfehlungen. Pädiatrie, 1, 1-7

https://www.rosenfluh.ch/media/paediatrie/2016/01/03_Krafttraining-im-Kindes-und-Jugendalter.pdf

Während noch in den Achtzigerjahren von einem Krafttraining für Kinder und Jugendliche abgeraten wurde, betrachtet man es heutzutage auch in diesem Lebensalter als eine zentrale Komponente körperlicher Aktivität. In diesem Artikel werden wichtige Aspekte für eine sichere und effektive Trainingsgestaltung diskutiert und altersspezifische Anpassungen im neuromuskulären System infolge des Krafttrainings vorgestellt.

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Prieske, O., Lesinski, M., Kriemler, S. & Granacher, U. (2017). Krafttraining im Kindes- und Jugendalter: Wirkungen, Anpassungsmechanismen und Empfehlungen. *Kinderärztliche Praxis*, 88 (2), 88-97

<http://www.kinderaerztliche-praxis.de/a/krafttraining-im-kindes-und-jugendalter-1813003>

Krafttraining im Kindes- und Jugendalter? Das haben Experten insbesondere in den 70er und 80er Jahren noch abgelehnt - heute nicht mehr. Wie aber gelingt die sichere und effektive Trainingsgestaltung, um die Ziele Leistungssteigerung und Gesunderhaltung zu erreichen? Auch altersspezifische Anpassungen im neuromuskulären System durch Krafttraining sind ein Thema dieses Artikels.

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Prieske, O., Mühlbauer, T., Kriemler, S. & Granacher, U. (2012). Krafttraining im Kindes- und Jugendalter. physioactive, 5, 31-36

<http://www.physioswiss.ch/index.cfm?nav=0,468&faqgruppeid=0&suchetxt=Krafttraining&detailid=1375,1342&scroll=0>

Krafttraining ist auch schon bei Kindern und Jugendlichen sinnvoll. Die AutorInnen erklären, wie der kindliche Körper auf den Trainingsreiz reagiert und wie das Training gestaltet werden sollte.

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Puta, C., Weber, S., May, R., Steidten, T., Hildebrandt, P., Gabriel, B., Herb-
sleb, M., Lesinski, M., Kellmann, M., Granacher, U. & Gabriel, H. (2016) Im-
mun-Score: Entwicklung eines benutzerfreundlichen Instruments zur
standardisierten Erfassung von Symptomen für die Differenzierung von
belastungsinduzierter und infektbasierter Stressreaktion im Nachwuch-
leistungssport. *Leistungssport*, 46(6), 15-18

<https://leistungssport.net/aktuelle-ausgabe/>

Im Nachwuchsleistungssport ist es aus Sicht gesundheitsrelevanter und leis-
tungsoptimierender Aspekte erforderlich, Zeichen einer immunologischen
Stressreaktion (infekt- und belastungsinduziert) zu erfassen und zu bewerten.
Hierfür wird in der KINGS-Studie der sogenannte Immun-Score entwickelt.
Erste Ergebnisse werden präsentiert.

Keywords: Krafttraining; Nachwuchsleistungssport; Immunsystem; Immun-
Score

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Wallenta, C., Granacher, U., Lesinski, M., Schünemann, C. & Mühlbauer, T. (2016). Einfluss eines Komplex- versus blockweisen Krafttrainings auf sportmotorische Leistungen von Nachwuchsleistungssportlern. *Sportverletzung Sportschaden*, 30(1), 31-37

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Background:

Muscle strength and speed are important determinants of soccer performance. It has previously been shown that complex training (CT, combination of strength and plyometric exercises within a single training session) is effective to enhance strength and speed performance in athletes. However, it is unresolved whether CT is more effective than conventional strength training that is delivered in one single block (BT) to increase proxies of athletic performance. Thus, the aim of the present study was to investigate the effects of CT versus BT on measures of muscle strength/power, speed, and agility in elite youth soccer players.

Methods:

Eighteen male elite youth soccer players conducted six weeks (2 sessions/week, 30 min. each) of progressive CT (n = 10, age: 18.5 ± 2.2 years) or BT (n = 8, age: 18.1 ± 1.6 years) in addition to their regular soccer training (approx. 6 sessions/week, 60-90 min. each). Before and after training, tests were conducted for the assessment of strength (one-repetition maximum [1RM] squat), power (countermovement jump [CMJ]), speed (30-m linear sprint), and agility (T test). Non-parametric analyses were used to calculate differences within (Wilcoxon test) and between (Mann-Whitney-U test) groups.

Results:

Both CT and BT proved to be safe (i.e. no training-related, but six match-related injuries reported) and feasible (i.e. attendance rate of ≥ 80% in both groups) training regimens when implemented in addition to regular soccer training. The statistical analysis revealed significant improvements from pre-training to post-training tests for the CT group in 1 RM squat (p = 0.043) and CMJ height (p = 0.046). For the BT-group, significantly enhanced sprint times were observed over 5 m (p = 0.039) and 10 m (p = 0.026). Furthermore, both groups significantly improved their t test time (CT: p = 0.046; BT: p = 0.027). However, group comparisons (CT vs. BT) over time (post-training minus pre-training test) did not show any significant differences.

Conclusion:

Six weeks of CT and BT resulted in significant improvements in proxies of athletic performance. Yet CT did not produce any additional effects compared to BT. Future research is needed to examine whether the observed test-specific changes, i.e. improvements in strength/power for the CT-group and improvements in speed for the BT-group, are due to the applied configuration of strength, plyometric, and sprint exercises or if they rather indicate a general training response.

Keywords: strength training; jump/sprint exercises; youth athletes

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KINGS-Studie

**KRAFTTRAINING IM
NACHWUCHSLEISTUNGSSPORT**

Publikationen - Buch

Mühlbauer, T., Roth, R., Kibele, A., Behm, D. G. & Granacher, U. (2013). Krafttraining mit Kindern und Jugendlichen: Praktische Umsetzung und theoretische Grundlagen. Schorndorf: Verlag Karl Hofmann

<http://www.sportfachbuch.de/index.php?cmd=show&typ=Buch&nr=2581>

Dieser Band beschäftigt sich mit den theoretischen Grundlagen und der praktischen Umsetzung von Krafttraining mit Kindern und Jugendlichen. Ausgehend von der Kennzeichnung der körperlichen Situation und der Kraftentwicklung im Kindes- und Jugendalter werden die Effekte von Krafttraining bei Kindern und Jugendlichen aufgezeigt. Hierzu zählen neben Verbesserungen der Kraftausdauer, der Maximal- und Schnellkraft, die Förderung elementarer und sportartspezifischer Fertigkeiten sowie die günstige Beeinflussung gesundheitsrelevanter Faktoren (u.a. Verletzungshäufigkeit, Knochenstatus, kardio-vaskuläre und psycho-soziale Kennwerte).

Im Anschluss werden neuronale und muskuläre Mechanismen zur Erklärung der trainingsbedingten Anpassungen beschrieben. Das Kernstück des Buches bildet die Darstellung und Beschreibung vielfältiger Übungsbeispiele für ein Krafttraining an Maschinen, mit Freihanteln, Zusatzgeräten, dem eigenen Körpergewicht und ein Sprungkrafttraining. Hierbei wurden insbesondere Übungen ausgewählt, die sich für den Einsatz im Schul- und Vereinssport eignen. Dieses Buch dient somit Lehrern, Übungsleitern und Trainern, ein zielgerichtetes Krafttraining mit Kindern und Jugendlichen wirkungsvoll und sicher durchzuführen.