Back Pain in Adolescent Athletes: Results of a Biomechanical Screening

Authors
Steffen Mueller[1], Juliane Mueller[1], Josefine Stoll[1], Michael Cassel[1], Anja Hirschmüller[2], Frank Mayer[1]

Affiliations
1 Sports Medicine & Sports Orthopaedics, University Outpatient Clinic, University of Potsdam, Potsdam, Germany
2 Rehabilitative and Preventive Sports Medicine, Medical Clinic, University Hospital Freiburg, Freiburg, Germany

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Correspondence
Dr. Steffen Mueller
Sports Medicine & Sports Orthopaedics
University Outpatient Clinic,
University of Potsdam
Am Neuen Palais 10
14469, Potsdam
Germany
Tel.: +49/331/977 1161, Fax: +49/331/977 1265
stefmue@uni-potsdam.de

ABSTRACT

The aim was to use a short biomechanical test battery to screen adolescent athletes with and without back pain to reveal relevant and possibly preventable deficits. 1 559 adolescent athletes (m/f 945/614; 13.2 ± 1.6y) were included. Back pain was assessed (1–5: 1 = no pain; 5 = maximum pain) for dichotomous categorization into back pain (BP: pain > 2, n = 113), healthy (NBP_{All}: pain = 1, n = 1 213) and matched healthy ($NBP_{matched}$: pain = 1, n = 113) athletes. Athletes performed stability, performance (jumps) and trunk strength testing. The center of pressure displacement [mm], jump height [cm], peak force [N], contact time [ms] and peak torque of the trunk [Nm] were analyzed. Analysis showed a statistically significant influence of trunk strength on back pain (BP/NBP_{ALL}). Nevertheless, after including co-variables (anthropometrics, gender and training volume), there were no significant variables detectable any longer. ANOVA identified no group differences ($BP/NBP_{matched}$) in the outcome measurement for the biomechanical tests ($p > 0.05$). This short biomechanical screening shows no sufficient differentiation in adolescent athletes for back pain. Therefore, age, training load and gender has greater relevance than strength deficits or postural control. This is challenging for further understanding of the complex conditions in young athletes with back pain.

Introduction

Valid and precise risk-factor screening is essential for sports injury prevention and rehabilitation [2]. Within the spectrum of injuries, the trunk, and especially the back, is a common site of pain and dysfunction already prevalent in adolescent athletes [27, 36]. Depending on the definition of back pain location (e. g., back, low back, upper back), time window (e. g., point, 3-month or lifetime prevalence) and investigated population (age, training volume), the reported prevalence differs considerably. However, the point prevalence of back pain is rather low in young athletes under 13 years of age (< 10 %). Nevertheless, at the age of 14, back pain prevalence in athletes is dramatically increased (> 20 %) [27, 36]. For 3–6 month back pain prevalence, even higher numbers (> 30 %) are shown for adolescent athletes [21, 29, 32]. For most of the cases, a structural correlate to back pain is still lacking, and therefore only non-specific back pain is diagnosed [39]. Even if well-defined risk factors are not evident, differences in function between healthy controls and back pain patients are known for adults [24, 28, 31].

As reported in numerous studies, different types of sports reveal specific demands on neuromuscular function [4, 28]. Nevertheless, Kibler et al. described the role and importance of core stability for all types of sports, whether running, throwing or jumping tasks [19]. High impact forces on the trunk are reported in gymnastics, rhythmic gymnastics, judo, weight lifting, rowing and jumping [16, 22, 30]. Repetitive loading with significant components of translation, rotation and reclination are believed to result in high impact forces [1, 18]. Therefore, it is proposed that athletes need a highly developed functional trunk capacity in order to compensate these sport-specific loads. If this ability is inadequate, athletes with high demands on trunk strength and stability will have a greater risk of sustaining an injury or developing back pain [1, 41]. This supports the recent theoretical approach of discussing reduced function and trunk stability not only as a result but also as a risk factor for back pain.

Reduced trunk extension strength has been shown in both untrained adults and adult athletes with back pain [28, 34]. Trunk strength capacity is therefore considered to be an essential marker compensating external forces and loads [19, 41]. In addition, trunk strength may directly or indirectly influence athletic performance in competition [7, 16, 19]. Thus, muscle strength can be seen as a relevant factor in preventing sports-related injuries in young athletes [7, 19]. Furthermore, Zazulak et al. showed an association between reduced core stability, reduced muscular trunk strength and a higher injury risk at the lower extremities in young (female) athletes [41]. Differences in trunk strength capacity depending on gender, age and sport type have been identified in healthy adults as well as adolescent athletes [13, 26, 28, 37]. Therefore it might not be valid to transfer results from untrained adults or adult athletes to adolescent athletes.

In addition, both postural control and complex neuromuscular control of movements are discussed as determinants used to quantify functional deficits in back pain [8, 33]. Associations between postural control and training experience are only evident in untrained adolescents. Biec and Kuczyński [6] showed improved postural control due to systematic training even in 13-year-old soccer players compared to non-athletes. Recent studies support the hypothesis that adults suffering from low back pain show reduced postural control [8, 33]. Nevertheless, it is unclear whether these results regarding prevention and rehabilitation are transferable to adolescent athletes. Further, pre-participation examinations in young athletes are frequently applied to evaluate eligibility for competitive sports, giving possibilities for additional functional screening to identify potential risk factors for back pain [23]. Screening tools should be capable of clearly detecting deficits between healthy and injured athletes. It has been hypothesized that reduced trunk strength, postural control and/or neuromuscular control, e. g., in complex movement tasks, negatively influences function and trunk stability, which results in an increased risk of back pain occurrence, recurrence or pain chronification [7]. Since this paradigm is getting increasing approval and exercise is one of the most evident treatments to prevent back pain reoccurrence or to reduce (acute/chronic) back pain, a valid short test battery to identify functional deficits is desired [7, 10, 15, 35]. A targeted allocation to specific exercise interventions enhancing these deficient factors is lacking but could possibly be derived from valid diagnostics to better prevent and treat back pain in athletes. Therefore, the test battery should involve postural control, strength capacity and complex high-intensity tasks to represent functional deficits.

Therefore, this study aims to investigate a short biomechanical test battery to screen adolescent athletes both with and without back pain in order to determine deficits valid to serve as risk factors for prevention strategies. Our hypothesis would lead to the expectation of reduced function, measurable by reduced postural control, jump performance and trunk strength in athletes with back pain.

Material and Methods

Subjects

2 389 adolescent athletes between 11 and 17 years of the elite schools of sports of the federal state of Brandenburg (inclusion criteria), Germany, were enrolled in the study. Athletes with contraindications for exercise, stance, jump or maximum trunk strength test and athletes with intake of pain medication were excluded by medical investigation. Due to incomplete datasets, N = 830 athletes had to be excluded for further analysis, resulting in N = 1 559 athletes (m/f 945/614; 13.2 ± 1.6; 163.2 ± 11.5 cm; 52.6 ± 13.7 kg; 8.4 ± 5.8 training h/week) for complete case analysis (Analysis I, IIa). The athletes come from 19 different sport types (artistic gymnastic (n = 19), boxing (n = 45), canoeing (n = 75), cycling (n = 113), finswimming (n = 6), handball (n = 196), horse riding (n = 70), judo (n = 109), karate (n = 4), pentathlon (n = 32), rowing (n = 100), shooting (n = 34), soccer (n = 202), swimming (n = 80), track and field (n = 210), triathlon (n = 11), volleyball (n = 56), weight lifting (n = 42), wrestling (n = 134), not defined (n = 21)). Additionally, a subgroup analysis of all back pain athletes (BP; n = 113) with 113 age- and gender-matched “no back pain” athletes ($NBP_{matched}$) was conducted (Analysis IIb).

All participants and their legal guardians were informed of the study and the specific testing procedures in a personal conversation with the principal investigator and through written study information during their stay at the university outpatient clinic. Before voluntary participation in the study, the legal guardians and children provided written informed consent. The University Ethical Committee approved all procedures conducted during the study [14].

Procedures

A cross-sectional study design was used to evaluate postural control (one-legged stance), jump performance and maximal trunk strength capacity in young athletes with and without back pain. All test situations were implemented as a biomechanical screening tool in the annual (pre-participation) examination of incoming and current students in elite sports schools [23, 26].

The test protocol started with a medical check-up to ensure that all participants were suitable for the upcoming biomechanical testing. In addition, anthropometric data and training history were assessed. Furthermore, subjective back pain was assessed using a standardized (face scale) questionnaire [25, 27]. Following this, all athletes underwent a general physical warm-up of at least 5 min prior to testing. The functional biomechanical screening tool included 3 tests. First, postural control (PC) was assessed during one-legged stance (barefoot, hands to the hip, view straight forward). After demonstration and one practice trial, 3 repetitions for left and right leg (randomized order) were performed for 10 s on a force plate (Amti OR6-6, Advanced Mechanical Technology, Inc., Watertown, MA, USA.) with 15 s rest between repetitions. The athletes had to keep their stance as stable and balanced as possible.

Second, complex motor performance was assessed via countermovement jumps (CMJ) and drop jumps (DJ). Initial instruction was followed by a demonstration and one practice trial before the jump measurements were performed. Always 3 repetitions were captured for CMJ and DJ with a ground reaction force plate (Amti OR6-6, Advanced Mechanical Technology, Inc., Watertown, MA, USA). DJ was performed from a box 20 cm in height. The rest period was set at 15 s between the 3 repetitions for each jump and 2 min between the 2 different jumps.

Third, maximum trunk strength capacity was assessed. The trunk strength measurement (TS) protocol began with a 90-s local warm-up and familiarization trial (isokinetic trunk flexion/extension), identical to the maximum test and performed at a moderate intensity. After a 60-s rest period, maximum isokinetic strength was tested concentrically at 60 °/s with 5 repetitions and a range of motion (ROM) of 55 ° (10 ° extension to 45 ° flexion; CON-TREX MJ TP 1 000; Physiomed Elektromedizin AG, Germany). Additional information for this standardized trunk testing protocol are detailed in a previous study [26] (▶ **Fig. 1**).

Outcome measurements and data analysis

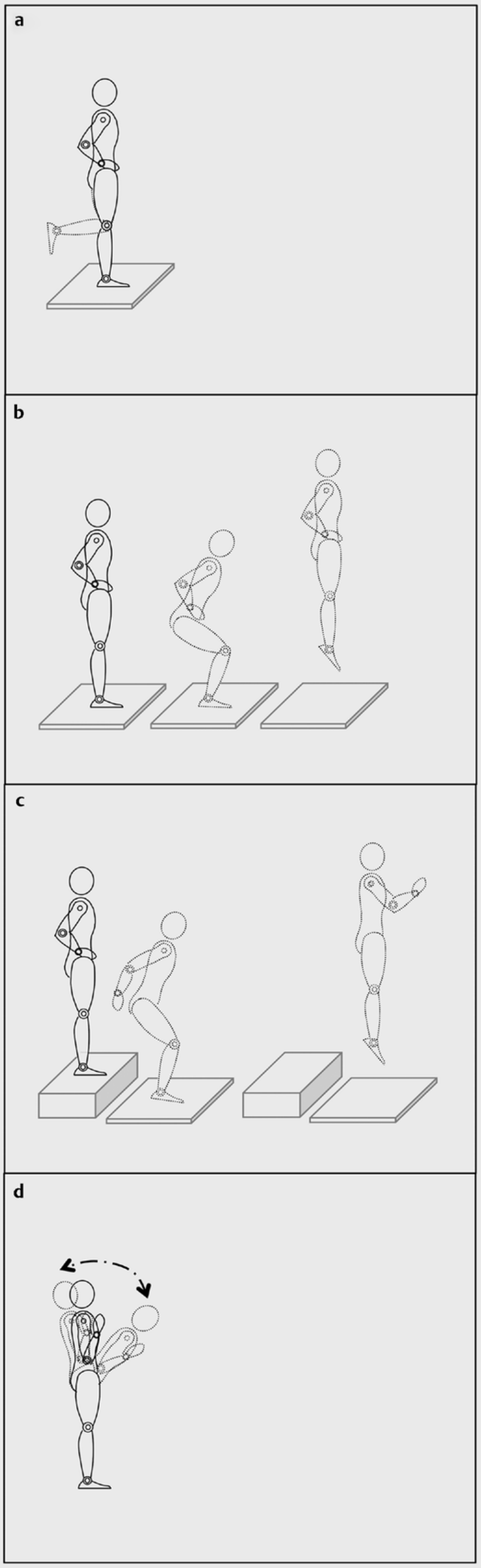
Subjective back pain was assessed using a standardized questionnaire consisting of a 5-step graded faces pain scale (FPS: face 1 = no pain; face 2 = little pain; face 3 = moderate pain; face 4 = strong pain; face 5 = maximum imaginable pain) [25, 27]. This type of questionnaire is considered valid for the use of subjective pain assessment in children and adolescents [20, 25].

The main outcome measurements analyzed for PC testing were the displacement [mm] of the centre of pressure (COP) in the anterior-posterior (a-p) and medio-lateral (m-l) directions, as well as the overall COP displacement (o) for the 10-s time interval analyzed (best trial (minimum) out of all left and right trials). For the jumps (CMJ/DJ), jumping height ($\text{Height}_{\text{CMJ/DJ}}$; computed from flight time using the formula: $1/8 * g\ [m/s^2] * \text{time}\ [s]^2$; [cm]), maximum peak force at take-off ($\text{Fz}_{\text{CMJ/DJ}}$; [N]) and ground contact time ($\text{Contact}_{\text{DJ}}$; [ms]) were calculated as the mean of 3 repetitions. Regarding trunk strength testing, absolute peak torque [Nm] in flexion (Flex_{abs}) and extension (Ext_{abs}) served as the main outcome measurements and were calculated as the mean of the 3 highest torque values from 5 repetitions [4, 26].

Statistical analysis

All non-digital data were documented in a handwritten case report form (CRF) and transferred to a database (JMP Statistical Software Package 8, SAS Institute®). All data ranges were checked for plausibility (e. g.: age: 11–18 years; body size: $1.40\,m > x < 2.00\,m$; body mass: < 120 kg; peak torque: < 400 Nm). Implausible data and extreme values were recalculated or revised.

Statistical analysis was done descriptively (frequency; mean ± standard deviation (SD); 95 % confidence interval CI) for all measurements, followed by multiple logistic regression and ANOVA ($\alpha = 0.05$, post hoc Tukey-Kramer) including calculation of effect size (G * Power 3.1.9.2; [d]). First, the multiple logistic regression was applied for the complete case data set (independent variable: biomechanical screening measurements; co-variables: anthropometric variables and training volume; dependent variable: back pain FPS). Second, in accordance with the FPS, athletes were classified as athletes with or without back pain: group “No Back Pain (All)” (NBP_{All}; FPS = 1 n = 1 213) and group “Back Pain” (BP; FPS > 2 n = 113). All athletes reporting pain on FPS = 2 (little pain: defined as no relevant pain) were excluded for this dichotomous group analysis [25]. Furthermore, a subgroup analysis of the n = 113 back pain athletes (BP) with n = 113 age- and gender-matched controls ($\text{NBP}_{\text{matched}}$) was conducted to account for the known anthropometric confounders [9, 26] (▶ **Fig. 2**). Anthropometric and training characteristics for matched groups ($\text{BP/NBP}_{\text{matched}}$) are detailed in ▶ **Table 1**. One-way ANOVA ($\alpha < 0.05$) was used to analyze differences for BP and $\text{NBP}_{\text{All}}/\text{NBP}_{\text{matched}}$.



▶ **Fig. 1** Functional biomechanical screening tests: **a** one-legged stance, **b** countermovement jump, **c**, drop jump and **d** maximum (isokinetic) trunk strength testing in extension/flexion.

Results

Complete case analysis

The pain questionnaire analysis revealed that 78 % of the athletes reported no pain (face 1; N = 1 213), 15 % little (face 2; N = 233), 5 % moderate (face 3; N = 85), 1 % strong (face 4; N = 22) and less than 1 % maximum pain (face 5; N = 6).

Regression analysis for the biomechanical variables showed a statistically significant influence of maximal trunk extension (Ext_{abs}; $Chi^2 = 0.0085$) and flexion strength ($Flex_{abs}$; $Chi^2 = 0.0015$) on back pain (generalized $r^2 = 0.11$). No influence was shown for all other biomechanical variables. After including the co-variables (age, training volume, gender, body height and mass) into the model, no biomechanical screening outcome measurement presented any more influence on back pain. In contrast, age ($Chi^2 < 0.0001$), training volume ($Chi^2 = 0.0028$) and gender ($Chi^2 = 0.0376$) presented an influence on back pain (generalized $r^2 = 0.17$).

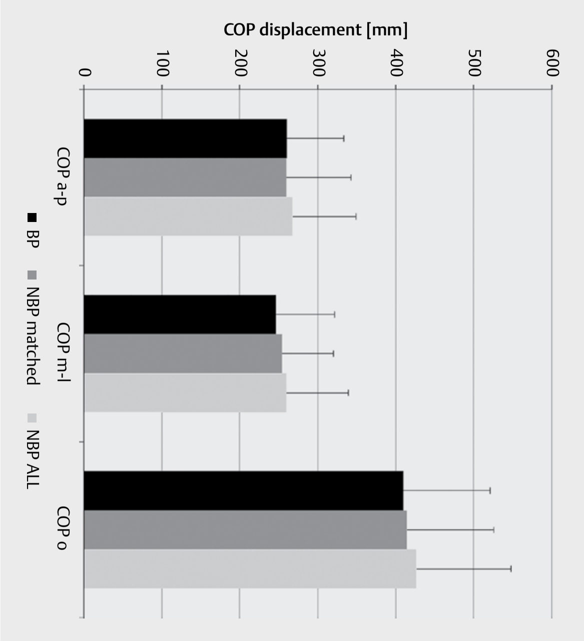
BP and NBP_{ALL} group analysis

Anthropometric and training data of BP and NBP_{All} showed that athletes without back pain were significantly younger, smaller and lighter. They also boasted fewer training years and training hours per week (▶ **Table 2A**). Additionally, analysis of the biomechanical screening tool resulted in differences between BP and NBP_{All} for jumping ($Height_{CMJ/DJ}$, $Fz_{CMJ/DJ}$) and trunk strength (Ext_{abs}, $Flex_{abs}$; $p < 0.05$), but not for the one-legged stance ($p > 0.05$; ▶ **Fig. 2**, **3**, **4**; ▶ **Table 1**).

BP and $NBP_{matched}$ group analysis

The matched-group analysis did not reveal any differences for anthropometric or training data between the groups BP and $NBP_{matched}$ (▶ **Table 2B**).

Overall, the COP displacement (postural control: PC) did not differ for BP compared to $NBP_{matched}$ as well as for the anterior-posterior and medio-lateral directions (▶ **Fig. 2**; $p > 0.05$).



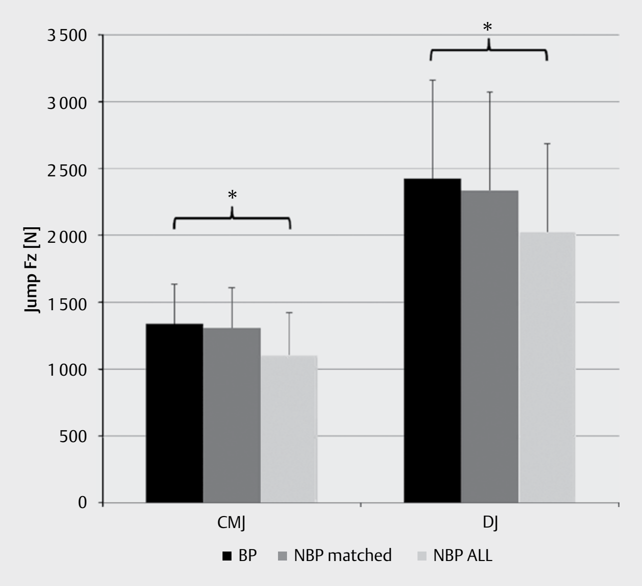
▶ **Fig. 2** COP displacement for anterior-posterior (COP_{a-p}), medio-lateral directions (COP_{m-l}) and overall distance (COP_o) [mm] for 10-s one-legged stance for athletes with (BP) and without ($NBP_{matched}$/NBP_{All}) back pain (mean ± SD)

▶ **Table 1** COP for anterior-posterior (COP_{a-p}), medio-lateral directions (COP_{m-l}) and overall (COP_o) displacement [mm], jumping performance (jump height: $Height_{CMJ/DJ}$ [cm]; ground contact time: $Contact_{DJ}$; [ms]) for countermovement jump (CMJ) and drop jump (DJ) and trunk peak torque (flexion and extension [Nm]) in athletes with (BP) and without (NBP_{All}; $NBP_{matched}$) back pain (mean ± SD, 95 % upper/lower CI; effect size d).

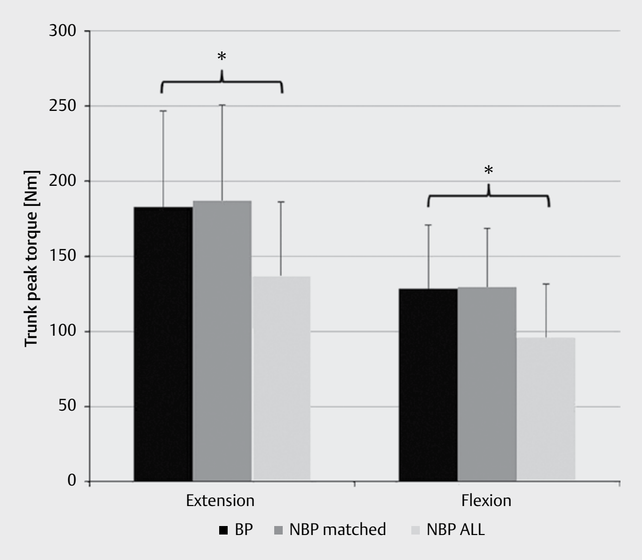
Groups	**COP**			**CMJ**	**DJ**		**Trunk Peak Torque**	
	COPa-p [mm]	**COPm-l [mm]**	**COPo [mm]**	**$Height_{CMJ}$ [cm]**	**$Height_{DJ}$ [cm]**	**$Contact_{DJ}$ [ms]**	**Extension [Nm]**	**Flexion [Nm]**
BP	261 ± 73 (246/276)	247 ± 75 (276/232)	410 ± 111 (232/261)	25.3 ± 5.0 (24.4/26.1)	26.2 ± 7.2 (26.1/25.1)	325 ± 109 (25/27)	183 ± 64 (174/192)	129 ± 42 (192/122)
$NBP_{matched}$	260 ± 83 (245/274)	255 ± 6 (274/241)	414 ± 111 (241/266)	25.9 ± 5.7 (24.8/26.9)	27.4 ± 7.1 (26.9/26.1)	329 ± 106 (26/29)	187 ± 64 (175/199)	130 ± 39 (199/122)
NBP_{All}	268 ± 81 (264/273)	260 ± 79 (273/255)	427 ± 121 (255/264)	24.3 ± 4.8 (24.1/24.6)	24.9 ± 6.1 (24.6/24.6)	314 ± 104 (25/25)	137 ± 49 (134/140)	96 ± 36 (140/94)
				p values				
$BP/NBP_{matched}$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
BP/NBP_{ALL}	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p = 0.0491$	$p = 0.0342$	$p > 0.05$	$p < 0.0001$	$p < 0.0001$
				effect size (d)				
$BP/NBP_{matched}$	0.012	0.042	0.042	0.117	0.168	0.038	0.064	0.022
BP/NBP_{ALL}	0.096	0.167	0.147	0.189	0.194	0.099	0.808	0.830

▶ **Table 2** Characteristics of adolescent athletes (anthropometric, back pain and training data) with (BP) and without back pain (NBP_{ALL}; $NBP_{matched}$).

A) Back pain category for all athletes						
Group	**Pain scale (FPS)**	**Gender [m/f]**	**Age [years]**	**Height [cm]**	**Weight [kg]**	**Training [h/week]**
NBP_{All}	1 (no pain)	741/472	12.9 ± 1.5	161.8 ± 11.1	50.8 ± 13.1	7.5 ± 5.2
	2	139/94	14.0 ± 1.8	166.8 ± 11.9	57.0 ± 13.9	10.5 ± 6.6
BP	3	50/35	14.6 ± 1.5	170.5 ± 11.3	61.5 ± 12.7	13.0 ± 6.2
	4	13/9	15.3 ± 0.6	172.7 ± 9.2	66.1 ± 12.6	14.0 ± 4.9
	5 (max pain)	2/4	14.8 ± 1.5	166.5 ± 14.9	63.0 ± 16.3	14.8 ± 5.4
B) Athletes with (BP) and matched athletes without ($NBP_{matched}$) back pain						
BP	3–5	65/48	14.7 ± 1.4	170.7 ± 11.1	62.5 ± 12.9	13.3 ± 5.9
$NBP_{matched}$	1	65/48	14.7 ± 1.4	170.6 ± 10.1	60.7 ± 11.4	12.8 ± 6.1



▶ **Fig. 3** Maximum peak force at take-off Fz [N] for countermovement jump (CMJ) and drop jump (DJ) for athletes with (BP) and without ($NBP_{matched}$/NBP_{All}) back pain (mean ± SD) (* $p < 0.05$).



▶ **Fig. 4** Flexion and extension trunk peak torque [Nm] for athletes with (BP) and without ($NBP_{matched}$/NBP_{All}) back pain (* $p < 0.05$).

All variables analyzed for the countermovement jump (CMJ) and drop jump (DJ) (Fz_{CMJ}, $Height_{CMJ}$, Fz_{DJ}, $Contact_{DJ}$, $Height_{DJ}$) did not show differences between $NBP_{matched}$ and BP (▶ **Table 1**, ▶ **Fig. 3**; $p > 0.05$).

Absolute peak torque in trunk flexion was 129.5 ± 39.0 Nm in the $NBP_{matched}$ group and 128.6 ± 42.4 Nm in the BP group. For trunk extension, the peak torque was 187.0 ± 63.3 Nm/182.9 ± 63.8 Nm in the $NBP_{matched}$/BP group. There are no statistically significant differences between BP and $NBP_{matched}$ ($p > 0.05$) in terms of absolute peak torque, in either flexion or extension (▶ **Fig. 4**).

Discussion

The purpose of this study was to evaluate whether a short biomechanical test battery could be used to identify the relevant variables influencing the presence of back pain and to differentiate between adolescent athletes with and without back pain. As a result, it could be shown that this functional biomechanical screening tool including postural control, trunk strength and jump performance testing does not differentiate between adolescent athletes with and without back pain.

Nevertheless, age and training volume could be shown as the main influencing factors and this is in line with the back pain prevalence in adolescent athletes [27, 36]. Athletes with back pain tend to be older and exposed to a higher training volume [27]. Similar findings are found for the overall injury rate of athletes between 7 to 18 years of age in a recent study by Jayanthi et al. [17]. This also leads to the hypothesis that the relationship of injury prevalence and training volume is U-shaped, meaning an excessive training load might affect injury risk. Nevertheless, it is unclear whether age or training volume itself leads to higher prevalence because the 2 factors coexist in the normal development of the athletes' training, and prospective studies are lacking [17].

Furthermore, the adolescent athletes showed an expected increase in trunk strength capacity, postural control, and jump performance along with increasing age and training volume independent of subjective back pain [26]. To account for this, a matched-group analysis was applied, diminishing any significant differences in the functional biomechanical testing. Therefore, previously reported and evident functional deficits, e. g., reduced postural control and reduced trunk extensor strength in adults with back pain are not transferable to highly trained adolescent athletes with back pain [8, 28, 34]. The investigation by Noll et al. could be relevant in this context [29]. Noll et al. found differences for trunk strength capacity that we did not find using the biomechanical test battery for our athletes with and without back pain [29]. One reason for these contradictory findings could be seen in the different characteristics of the investigated participants. Our athletes were more than 3 years younger and had an extremely higher training volume. Furthermore, the duration of back pain is not equal in the studies and could additionally influence the results. Especially highly trained (elite) athletes (≈ 13 h/week) with back pain may evidence fewer effects in biomechanical variables compared with low or moderately trained athletes (1–6 training sessions/week) [29].

Potentially, the equivalent training volume for BP and $\text{NBP}_{\text{matched}}$ athletes could be discussed as one possible reason for the lack of functional deficits.

Therefore, disuse and deconditioning often seen in adults with (chronic) low back pain is probably not present in adolescent athletes [3, 40].

Current literature discusses increased age and training load as risk factors for back pain in adolescent athletes, often assessed with self-reported standardized questionnaires [5, 27, 36]. These factors correspond to the findings presented here, namely that anthropometrics and training volume are the main factors that differentiate between BP and NBP_{All}/$\text{NBP}_{\text{matched}}$. These findings are supported by Trainor & Wiesel [38], who reported that a sudden change in the training process, including increased volume, is a common cause of back pain. In addition, in a recent study with adolescent non-athletes, Bernard et al. [5] concluded that training volume and loading at this stage of development (adolescence) and sports career (transition to high-performance sports) should be increased with caution. Coaches, physicians and clinicians working with adolescent high-performance athletes need to consider these results in order to counteract back pain development with prevention strategies and adapted training volumes.

Differences between adults with and without back pain have been shown on a neuromuscular level. Reduced muscular reaction time of the trunk-encompassing muscles to sudden, unexpected loading is considered to be one factor eliciting low back pain [11, 31]. Consequently, the inadequate neuromuscular compensation of sudden, repetitive loading is discussed as a risk factor for back pain development in athletes [11, 31]. Therefore, a more complex biomechanical screening tool including electromyography analysis and more challenging testing situations (e. g., perturbations) might be useful to detect differences between adolescent athletes with and without back pain [11, 31]. However, the feasibility and transfer of such complex biomechanical measurement tools to daily practice have to be discussed critically. In contrast, a short test-battery could possibly be implemented in preparticipation examinations and annual health checks or regular field tests conducted by coaches during training sessions. For transfer into the field, postural control and jump performance could be easily assessed by affordable and valid force sensors and (isometric) trunk strength capacity by sequence apparatus [12].

Nonetheless, certain limitations of the study have to be discussed. It must be mentioned that the athletes analyzed were recruited out of 19 different types of sports, presenting different demands on trunk strength capacity and stability during performance [4, 28]. Therefore, athletes from different types of sports might have different levels of postural control, trunk strength and jump performance, but there were no differences in distribution of the athletes with and without back pain in terms of the different types of sports included in the analysis.

Moreover, pain assessment and (low) back pain classification might be discussed as an influencing factor on the results presented here and comparability with the literature. In general, the faces pain scale (FPS) questionnaire has been validated for the use of pain assessment in children and adolescents [20, 25] and seems to be a suitable tool for a feasible transfer into the practical field of sports (e. g., coaches) and sports medicine (e. g., physiotherapists) to identify athletes in pain.

Practical implications

A feasible short biomechanical screening tool including postural control, jump performance and trunk strength testing is not able to identify the influencing factors in back pain or to differentiate between adolescent athletes with and without back pain. Therefore, the biomechanical test battery is not valid for application. In contrast, adolescent athletes with BP are significantly older with higher body weight and size compared to healthy ones. In addition, adolescent athletes with BP have significantly more training years and training volume compared to healthy ones. Therefore, age and training volume are relevant factors at this stage of development and sports career and must be considered during the training process [2, 3]. For future investigation, this implies the need for special attention to training load (volume, intensity) in combination with biomechanical characteristics. Furthermore, a neuromuscular approach using EMG analysis and perturbation tests, for example, might be beneficial. Finally, this evidence demands an adaptation of perspective warranted by the possible presence of a specific or complex condition in elite adolescent athletes with back pain.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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