

Abstract

Objectification, comparison, and degree of association of maladaptive indicators in athletes

Aim: The aim of this study was to identify bilateral and unilateral asymmetries in different components of neuromuscular testing among young athletes, and compare these asymmetries with respect to sport type, age group, performance level, and gender. The secondary aim was to assess the degree of association between types of asymmetry (morphological, balance, strength, and running asymmetry).

Methods: The sample population consisted of young male and female athletes aged 10 to 19 with various sports specializations. The participants were grouped by various factors: predominant characteristic of the sport (symmetrical (SY), asymmetrical (ASY), hybrid (HY)); chronological age (10–12 years, 13–15 years, 16–18 years); performance level (elite, sub-elite), and gender. Asymmetry was assessed from morphology and various neuromuscular assessments: distribution of muscle mass on the lower limbs (MA), bilateral differences in the size of the center of pressure path length (APS), maximum active (APF) and impact peak force (IPF) and force impulse (FI) at initial (Z) and final (K) running speed, bilateral asymmetry of knee extensors (Q:Q) and flexors (H:H), and H:Q ratio (unilateral asymmetry) at three angular velocities (low = 60°/s, medium = 180°/s, high = 300°/s), bilateral force deficits (BFD) during countermovement jump (CMJ) and squat jump (SJ).

Results: The average values of bilateral asymmetry across selected parameters expressed in relative values (%) were in accordance with arbitrary thresholds (< 15 %), with the exception of APS. Asymmetries of less than 10 % were identified in 38.0–91.4 % of athletes, 6.6–18.7 % achieved increased asymmetry (10–15 %), and 2.0–43.9 % of athletes achieved significant asymmetry (>15 %), depending on the test. The direction of bilateral asymmetry showed a slight tendency toward the dominant lower limb, although this was not seen in every assessment, particularly for the Q:Q at all angular velocities. Significantly lower H:H¹⁸⁰ values were found in the ASY group compared to the SY and HY groups ($F = 13.62$; $p < 0.05$, $\eta^2 = 0.04$). Conversely, ASY group achieved significantly higher values compared to the SY group in BFD^{SJ} ($F = 3.59$; $p < 0.05$, $\eta^2 = 0.01$). Significantly higher values of the H:Q ratio at all angular velocities in HY group were found compared to the ASY and SY groups ($F = 3.82–16.04$, $p < 0.05$, $\eta^2 = 0.01–0.04$). Significantly lower values in category 16–18 years in Q:Q¹⁸⁰, Q:Q³⁰⁰, APF^Z, APF^K compared to the category 10–12 years were found ($F = 5.72–9.33$, $p < 0.05$, $\eta^2 = 0.02–0.03$). Significantly higher values of the H:Q ratio at all angular velocities for both limbs

in the male group compared to the female group were observed ($t = 4.90-7.69$, $p < 0.05$, $d = 0.42-0.68$). The degree of association between types of asymmetry (morphological vs. strength) was trivial for all parameters ($r < 0.1$).

Conclusions: The analysis revealed statistically significant differences in the magnitude of bilateral and unilateral asymmetries among the selected groups of athletes, albeit with small to medium effect sizes. Assessment of asymmetries in terms of magnitude and direction should be performed at an individual level due to the high number of players identified with increased (10-15 %) or significant bilateral asymmetry (> 15 %). The inconsistency in the direction of bilateral asymmetry has a significant impact on designing movement interventions aimed at reducing bilateral asymmetries. Strength and conditioning coaches of specific sports (SY and ASY) especially in women's groups should focus on reducing unilateral asymmetry by developing the strength of knee flexors. The presented values could serve as reference values for uninjured players within the observed groups.

Keywords: bilateral asymmetry, unilateral asymmetry, sports specialization, age categories, performance level, intersex differences.