



Handgrip Strength as an Independent Correlate of Physical Fitness in Amateur Padel Players: A Cross-Sectional Study

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Abstract

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Padel is rapidly expanding worldwide, but the fitness profile of adult amateur players remains incompletely characterized. This cross-sectional study examined associations between handgrip strength (HGS) and field-based physical fitness in 87 amateur padel players (45 self-reported males, 42 self-reported females; age: 40.0 ± 10.1 years), the association between bioelectrical impedance phase angle and HGS, and, exploratorily, links between padel training volume and SF-36 summary scores. Participants completed HGS dynamometry, a pre-planned change-of-direction T-test, countermovement jump (CMJ), 20 m sprint, Yo-Yo Intermittent Recovery Test Level 1 (YYIR1), bioelectrical impedance analysis, and the SF-36. After adjustment for sex, age, and body mass index, relative HGS remained associated with CMJ height ($r_{\text{partial}} = 0.34$, Holm-adjusted $P = .004$), sprint time ($r_{\text{partial}} = -0.35$, Holm-adjusted $P = .003$), and YYIR1 distance ($r_{\text{partial}} = 0.27$, Holm-adjusted $P = .024$), but not T-test time ($r_{\text{partial}} = -0.13$, Holm-adjusted $P = .223$). Primary and extended regression models yielded the same pattern, and body-mass-adjusted models using absolute HGS supported the robustness of these findings. No HGS $\times$ sex interaction remained significant after Holm correction. Phase angle was associated with relative HGS after adjustment ($r_{\text{partial}} = 0.41$, Holm-adjusted $P < .001$). Training volume showed modest positive associations with SF-36 physical and mental component summary scores. Relative HGS may provide a simple correlate of general neuromuscular fitness in amateur padel players, while phase angle may offer complementary physiological information; prospective studies are required before either measure can be interpreted as a marker of padel-specific performance.

Keywords: Racket sports, field tests, quality of life, phase angle, bioelectrical impedance

Introduction

Padel is a doubles racket sport played on an enclosed 20×10 m court divided by a net. Current International Padel Federation rules limit the racket to a maximum total length of 45.5 cm, a maximum width of 26 cm, a maximum head thickness of 38 mm, and a maximum handle length of 20 cm.¹ The walls are integral to play, allowing the ball to rebound from the lateral and rear surfaces. Time-motion analyses characterize padel as an intermittent sport; in official Italian sub-elite competition, mean rally duration was approximately 6.7 s and mean match duration approximately 54 min, although temporal characteristics vary with competitive level and format.² These characteristics entail repeated short accelerations, decelerations, lateral displacements, and overhead strokes, together with repeated racket handling across intermittent rallies.^{3,4} Because the enclosed court compresses the playing area, the number of discrete actions

per player tends to exceed that observed in tennis or badminton.⁵ Originally developed in Mexico in the late 1960s, padel has since grown at a remarkable pace: current estimates place global participation at approximately 35 million amateur players across more than 150 countries, with especially strong growth in Southern Europe, including Spain and Italy.⁶ Spanish participation data further document substantial uptake across both sexes and a broad adult age range.^{7,8}

A point that is sometimes overlooked in this growth narrative, however, is that the physical fitness profile of recreational padel players remains only partially characterized.⁹ Although padel research has predominantly focused on elite competitors, documenting predominantly mesomorphic somatotypes with a substantial endomorphic component^{5,10} and an intermittent match-play structure that elicits moderate-intensity efforts at roughly 40–50% of $\text{VO}_{2\text{max}}$,^{3,9} some studies have also examined younger amateur players, adult women, and intermediate-level male players.^{11–13} Even so, the available evidence in adult amateur padel players remains fragmented and insufficiently characterized, particularly in relation to simple field-based screening markers and their independence from major confounders such as sex, age, and body size. This gap matters practically, because evidence-based guidance on fitness screening and health promotion in recreational padel cannot be developed without a clearer characterization of this population.

Handgrip strength assessment has established itself as a simple, low-cost method for assessing muscular strength across diverse populations.^{14–15} The rationale for expecting handgrip strength to correlate with whole-body – and specifically lower-limb – performance rests on evidence that grip strength shares variance with lean body mass and with measures of lower-limb strength and power.^{15,16} In their systematic review, Szaflik et al¹⁵ found that the magnitude of associations between HGS and strength measures varied substantially across populations and testing methods. McBride et al¹⁶ demonstrated strong associations between HGS and lower-limb strength, CMJ performance, thigh muscle cross-sectional area, and lean body mass across adults aged 18–64 years. HGS is included in established fitness-testing batteries for tennis players.¹⁷ In a mixed-sex cohort of Physical Education students aged 19–25 years, Martín Simón and Rojano Ortega reported correlations between HGS and CMJ height ($r = 0.59$) and 20 m sprint time ($r = -0.54$).¹⁸

Padel, in particular, offers a sport-specific rationale for investigating handgrip strength beyond its general utility as a screening tool. Repeated racket handling occurs across intermittent rallies that include volleys, overhead strokes, and defensive actions following wall rebounds.^{3,4} To date, no full-length peer-reviewed study appears to have examined whether handgrip strength is independently associated with lower-limb power, sprint performance, change-of-direction performance, and intermittent endurance in adult amateur padel players after accounting for major confounders such as sex, age, and body size.

Bioelectrical impedance analysis (BIA) parameters have attracted growing attention as indicators of tissue and cellular characteristics. Phase angle, derived from the relationship between reactance and resistance, is commonly interpreted in relation to cellular properties and body cell mass, while raw impedance and BIVA patterns also provide information on hydration and fluid distribution.^{19,20} In resistance-trained men, Fukuoka et al²¹ reported that phase angle remained associated with countermovement jump height and bench press strength after adjustment for lean soft tissue and fat mass. Phase angle has also been associated with short-term maximal-intensity performance in soccer players and with physical-fitness indicators, including HGS, in adolescents^{22,23} and, more recently, in elite female volleyball players, where a strong bivariate correlation between phase angle and handgrip strength ($r = 0.73$) was observed.²⁴ However, no

prior padel-specific studies appear to have examined the association between phase angle and handgrip strength.

A third dimension that warrants attention – though it stands somewhat apart from the fitness-assessment core of the present investigation – is the relationship between recreational sport participation and health-related quality of life. Systematic evidence supports a positive association between sport engagement and psychological well-being,²⁵ and epidemiological data indicate that participation in racket sports is associated with lower cardiovascular and all-cause mortality, independently of socioeconomic confounders.^{26,27} Padel-specific evidence on health-related quality of life and wellbeing remains limited, with the existing literature focusing more often on performance-related psychological constructs such as anxiety, self-confidence, and mental fatigue than on broader quality-of-life outcomes.²⁸

The present study, therefore, had three aims: (1) to investigate the relationship between handgrip strength and field-based physical fitness performance in amateur padel players, including the extent to which this relationship persists after controlling for sex, age, and body mass index; (2) to examine the association between phase angle and handgrip strength; and (3) on an exploratory basis, to assess the relationship between padel practice volume and health-related quality of life. Based on previously reported HGS-CMJ and HGS-sprint associations,¹⁸ it was hypothesized that handgrip strength would demonstrate moderate bivariate correlations with countermovement jump and sprint performance (expected $|r| \approx 0.50\text{--}0.60$), with smaller associations after adjustment for sex and anthropometric confounders. Phase angle was hypothesized to show a positive association with handgrip strength, consistent with the strong bivariate association previously reported in elite female volleyball players.²⁴ For the exploratory quality-of-life aim, a positive but modest association between training volume and SF-36 summary scores was anticipated.

Methods

Participants

This cross-sectional study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.²⁹ Participants were recruited through convenience sampling from five padel clubs in Northern Italy between February and April 2025.

The sample size was determined a priori using G*Power (version 3.1.9.7; $\alpha = 0.05$, $1 - \beta = 0.80$, expected $r = 0.30$, conservatively specified below previously reported HGS-CMJ and HGS-sprint correlations in a mixed-sex young-adult cohort¹⁸), yielding a minimum requirement of 84 participants for the primary bivariate correlation analysis. The study was not designed or powered to test between-sex mean differences; sex-disaggregated participant characteristics are therefore reported descriptively rather than as inferential outcomes. With $N = 87$, the primary four-predictor regression models provided approximately 22 observations per predictor and the extended six-predictor models approximately 15 observations per predictor. For the extended models, this exceeded the 10 observations-per-predictor minimum heuristic discussed for regression models with six or more predictors.³⁰ These ratios were treated as descriptive rather than as formal power criteria. A post-hoc sensitivity calculation indicated 80% power to detect an overall effect of approximately $f^2 = 0.17$ in a six-predictor model at $\alpha = .05$.

Inclusion criteria were: (1) age between 18 and 60 years; (2) regular padel practice (at least two sessions per week for the previous six months); (3) amateur competitive status; and (4) absence

of musculoskeletal injuries in the preceding three months. Exclusion criteria included: (1) professional sports participation; (2) cardiorespiratory, metabolic, or neurological disorders; and (3) use of medications known to affect muscular performance.

A total of 87 amateur padel players were enrolled. Sex was self-reported by participants on the standardized anamnesis form using the response options; 45 participants reported male sex and 42 reported female sex. No exclusion criterion based on intersex status was specified in the study protocol. Participant characteristics are presented descriptively overall and by self-reported sex in Table 1; no inferential tests of between-sex differences were performed.

Table 1. Participant characteristics overall and by self-reported sex.

Variable	Total (N = 87)	Males (n = 45)	Females (n = 42)
Age (y)	40.0 ± 10.1	39.8 ± 10.7	40.3 ± 9.5
Padel experience (mo)	28.0 ± 13.7	26.4 ± 13.1	29.8 ± 14.2
Training frequency (sessions/wk)	3.0 ± 0.9	3.3 ± 0.9	2.7 ± 0.8
Training volume (h/wk)	4.0 ± 1.0	4.4 ± 1.1	3.6 ± 0.8
Stature (cm)	172.7 ± 7.8	178.9 ± 5.0	166.0 ± 3.8
Body mass (kg)	72.5 ± 9.5	80.3 ± 5.9	64.3 ± 4.2
BMI (kg/m ²)	24.2 ± 1.8	25.1 ± 1.5	23.4 ± 1.7
Body fat (%)	24.4 ± 6.6	19.4 ± 3.8	29.6 ± 4.6
Lean body mass (kg)	55.1 ± 10.4	64.4 ± 4.2	45.2 ± 3.5
Waist circumference (cm)	84.1 ± 6.7	88.7 ± 5.1	79.2 ± 4.4
Phase angle (°)	6.1 ± 0.7	6.6 ± 0.5	5.5 ± 0.4
HGS absolute (kg)	40.3 ± 11.1	49.2 ± 6.9	30.7 ± 4.9
HGS relative (kg/kg)	0.55 ± 0.10	0.61 ± 0.07	0.48 ± 0.07
T-test time (s)	11.36 ± 1.06	10.70 ± 0.80	12.05 ± 0.82
CMJ height (cm)	26.0 ± 7.2	31.9 ± 4.4	19.7 ± 2.8
20 m sprint (s)	3.66 ± 0.36	3.37 ± 0.19	3.97 ± 0.23
YYIR1 distance (m)	852 ± 304	1066 ± 254	622 ± 140
SF-36 PCS	54.4 ± 3.5	55.0 ± 3.4	53.8 ± 3.5
SF-36 MCS	51.9 ± 4.1	52.6 ± 3.8	51.1 ± 4.2

Note: Values are mean ± SD and are presented descriptively; no inferential tests of between-sex differences were performed. HGS = handgrip strength; CMJ = countermovement jump; YYIR1 = Yo-Yo Intermittent Recovery Test Level 1; PCS = physical component summary; MCS = mental component summary.

The study was conducted in accordance with the Declaration of Helsinki,³¹ and the protocol was approved by the University Territorial Ethics Committee (reference: UTEC 2023-016). All participants provided written informed consent prior to their involvement in the study. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.³² Personal data were processed in compliance with the General Data Protection Regulation.

Protocol

All assessments were conducted in a single session at each padel club under standardized conditions (ambient temperature: 20–22 °C; relative humidity: 50–60%). Participants were instructed to avoid strenuous exercise for 48 hours and caffeinated beverages for 12 hours before testing. Assessments were performed in the following fixed order: (1) anthropometric measurements and body composition analysis; (2) handgrip strength testing; (3) SF-36 questionnaire administration; and (4) field-based physical fitness tests. A standardized recovery period of 10–15 minutes was provided between each field test to minimize the influence of cumulative fatigue.

Anthropometric measurements and body composition.

Body mass and stature were measured using a calibrated scale and stadiometer (Seca 213, Hamburg, Germany) to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI) was calculated as body mass divided by stature squared (kg/m^2). Waist circumference was measured at the midpoint between the lower border of the ribcage and the iliac crest.

Bioelectrical impedance measurements were performed using the BIA 101 (Akern, Florence, Italy), which operates at a single frequency of 50 kHz and provides resistance, reactance, and phase angle values. To reduce measurement variability related particularly to hydration status,³³ BIA was performed under standardized pre-test conditions; the study protocol required participants to abstain from food and drink for at least 4 hours before testing, avoid strenuous exercise for at least 48 hours prior (as per the general protocol), and empty their bladders immediately before assessment. Participants were positioned supine on a non-conductive surface with limbs abducted at approximately 30–45°. After cleansing the skin with alcohol, four disposable electrodes (Biatrodes, Akern Srl, Florence, Italy) were placed on the dorsal surface of the right hand (distal metacarpus and between the distal prominences of the radius and ulna) and the dorsal surface of the right foot (distal metatarsus and between the medial and lateral malleoli), following standard tetrapolar configuration.³⁴ Phase angle was calculated as the arctangent of reactance divided by resistance, multiplied by $180^\circ/\pi$. An identical BIA protocol has been described in detail elsewhere.²⁴

Handgrip strength.

Handgrip strength was measured using a calibrated Jamar Plus+ digital dynamometer (Patterson Medical, Warrenville, IL, USA). Testing position followed the American Society of Hand Therapists' recommendations: participants were seated with the shoulder adducted, the elbow flexed at 90°, and the forearm in a neutral position.³⁵ Three maximal voluntary contractions were performed with each hand, alternating between hands with 60 seconds of rest between trials. The highest force recorded across the six trials was retained as the participant-level measure of maximal HGS, consistent with recent international recommendations to perform three repetitions per hand and calculate absolute HGS as the maximum value irrespective of hand.³⁶ Relative HGS was calculated as absolute HGS divided by body mass using the unrounded source values.

Health-related quality of life.

The validated Italian version of the Short Form Health Survey (SF-36) was administered.³⁷ Its Italian validation comprised seven studies including more than 7,000 participants. In the 2,031-person normative sample, Cronbach's α ranged from 0.77 to 0.93 across the eight scales; in a separate 100-patient sample, 3-day test-retest correlations ranged from 0.72 to 0.89 across the five scales assessed. Scaling assumptions and construct validity were also supported. Physical component summary (PCS) and mental component summary (MCS) scores were computed according to standard scoring procedures.

Physical fitness field tests.

Four tests were administered in the following fixed sequence: (1) the T-test, a pre-planned change-of-direction task,³⁸ measured with electronic timing gates (Witty, Microgate, Bolzano, Italy) - participants completed two familiarization trials followed by two timed trials, and the best time was recorded; (2) the countermovement jump (CMJ), assessed using an optical detection system (Optojump Next, Microgate, Bolzano, Italy), with jump height calculated from flight time - three trials were performed, and the highest value was retained; (3) the 20 m sprint, timed with

electronic gates placed at 0 and 20 m - the best of two trials was recorded; and (4) the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1),³⁹ recording total distance covered.

Intra-session reliability, computed from repeated trials, was acceptable for all multi-trial tests: HGS ICC(3,1) = 0.95 (95% CI: 0.91-0.97, CV = 4.5%), CMJ height ICC(3,1) = 0.93 (95% CI: 0.88-0.96, CV = 5.2%), 20 m sprint ICC(3,1) = 0.89 (95% CI: 0.82-0.94, CV = 2.8%), and T-test ICC(3,1) = 0.84 (95% CI: 0.75-0.90). The YYIR1 was administered once because it is an exhaustive test; therefore, study-specific intra-session reliability could not be estimated from the present protocol. Published test-retest studies support high reproducibility for the YYIR1, including a coefficient of variation of 4.9% in the original adult study and ICCs of 0.87–0.95 in high-level youth soccer players.^{39,40}

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (version 29; IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as mean $\pm$ standard deviation. Participant characteristics are reported descriptively overall and by self-reported sex, without inferential between-sex comparisons. Bivariate relationships were quantified using Pearson correlation coefficients (r) with 95% confidence intervals obtained from Fisher's z transformation. Pearson's r was selected as the bivariate effect-size measure because it conveys both the magnitude and direction of the association. Separate R^2 values were not reported because, for simple bivariate associations, they are algebraically determined by r and do not retain the direction of the association. Partial correlations evaluated HGS–fitness and phase angle–HGS associations after controlling for sex, age, and BMI.

Multiple linear regression was conducted separately for each physical-fitness outcome. Primary models included relative HGS, self-reported sex (0 = female, 1 = male), age, and BMI. Extended models additionally included padel experience and weekly training volume. For relative HGS, unstandardized coefficients are interpreted per 0.10 kg/kg increase. Standardized coefficients (β), 95% confidence intervals, model R^2 , and the partial R^2 attributable specifically to HGS are reported. Multicollinearity was evaluated using variance inflation factors (VIF), and residual diagnostics were inspected for linearity, normality, and homoscedasticity. Where heteroscedasticity was suggested, HC3 robust standard errors were examined as a sensitivity check.

Sex was examined as a potential effect modifier by adding a mean-centered relative HGS $\times$ sex interaction term to each adjusted primary model; the interaction analyses were repeated in the extended models. Because ratio scaling may generate body-size-dependent associations, sensitivity analyses replaced relative HGS with absolute HGS and included body mass as a covariate together with sex and age. A secondary sensitivity analysis substituted lean body mass for body mass; these estimates were interpreted cautiously because of increased multicollinearity.

All tests were two-sided with $\alpha = .05$. Holm's sequential procedure was applied within prespecified families, and both uncorrected and Holm-adjusted P values are reported: (1) four fitness partial correlations for absolute HGS; (2) four fitness partial correlations for relative HGS; (3) four HGS coefficients in the primary regressions; (4) four HGS coefficients in the extended regressions; (5) four HGS $\times$ sex interaction tests within each model set; (6) four body-mass-adjusted absolute-HGS sensitivity models; (7) the two phase angle-HGS associations; and, for the exploratory quality-of-life aim, (8) the two training-volume associations with PCS and MCS, evaluated separately for bivariate and adjusted analyses. This definition of families reflects the three prespecified study aims and avoids combining conceptually distinct primary and exploratory hypotheses.

Results

Handgrip Strength and Physical Fitness Performance

Bivariate and adjusted associations between HGS and field-test performance are presented in Table 2. At the bivariate level, absolute and relative HGS were moderately to strongly associated with all four field tests ($|r| = 0.55$ - 0.82 , all $P < .001$). Figure 1 presents the pooled bivariate relationships for relative HGS.

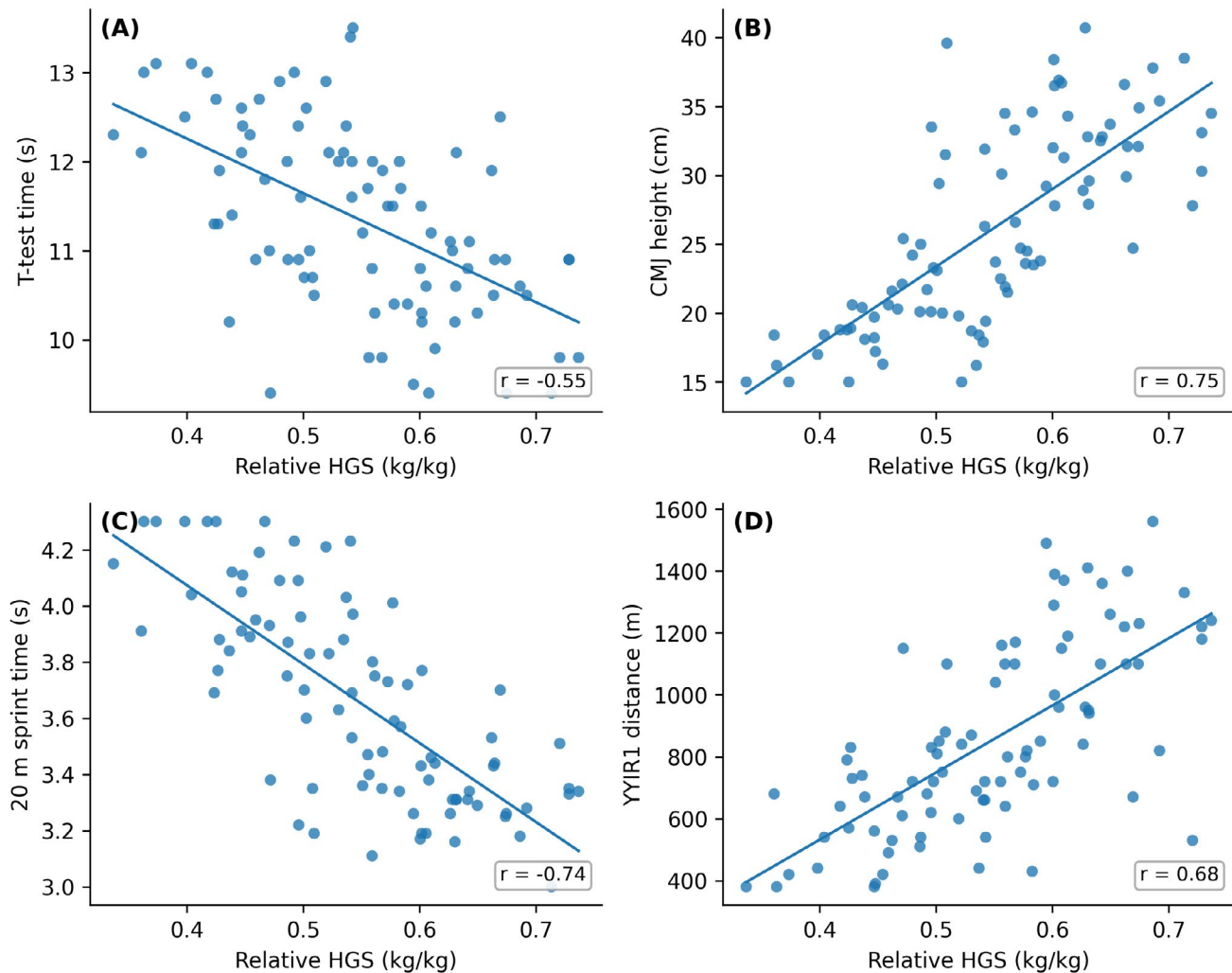


Figure 1. Pooled bivariate relationships between relative handgrip strength (kg/kg) and field-based physical fitness in 87 amateur padel players. (A) Pre-planned change-of-direction T-test time. (B) Countermovement jump height. (C) 20 m sprint time. (D) Yo-Yo Intermittent Recovery Test Level 1 distance. Pearson correlation coefficients are displayed.

After controlling for sex, age, and BMI, relative HGS remained associated with CMJ height ($r_{\text{partial}} = 0.34$, $P = .0013$, $P_{\text{Holm}} = .0037$), 20 m sprint time ($r_{\text{partial}} = -0.35$, $P < .001$, $P_{\text{Holm}} = .0034$), and YYIR1 distance ($r_{\text{partial}} = 0.27$, $P = .0119$, $P_{\text{Holm}} = .0238$), but not T-test time ($r_{\text{partial}} = -0.13$, $P = .223$, $P_{\text{Holm}} = .223$). Absolute HGS showed the same general pattern: adjusted associations remained significant for CMJ, sprint, and YYIR1 after Holm correction, including the absolute HGS-YYIR1 association ($r_{\text{partial}} = 0.24$, $P = .0231$, $P_{\text{Holm}} = .0463$), whereas the T-test association was not significant (Table 2).

Table 2. Bivariate and partial correlations between handgrip strength, phase angle, and physical fitness.

Variable	Absolute HGS r (r_{partial})	P	P_{Holm}	Relative HGS r (r_{partial})	P	P_{Holm}
T-test time (s)	-0.62 (-0.12)	.249	.249	-0.55 (-0.13)	.223	.223
CMJ height (cm)	+0.82 (+0.30)	.004	.016	+0.75 (+0.34)	.001	.004
20 m sprint (s)	-0.80 (-0.31)	.004	.016	-0.74 (-0.35)	<.001	.003
YYIR1 distance (m)	+0.73 (+0.24)	.023	.046	+0.68 (+0.27)	.012	.024
Phase angle (°)	+0.77 (+0.33)	.002	.002	+0.75 (+0.41)	<.001	<.001

Note: Values are bivariate r with r_{partial} in parentheses; partial correlations control for self-reported sex, age, and BMI. P is the uncorrected P value for the partial correlation, and P_{Holm} is the Holm-adjusted value. Fitness outcomes were corrected as separate four-test families for absolute and relative HGS; phase angle associations were corrected as a two-test family. For all bivariate correlations, both uncorrected and Holm-adjusted P values were < .001. HGS = handgrip strength; CMJ = countermovement jump; YYIR1 = Yo-Yo Intermittent Recovery Test Level 1.

Primary and extended regression models are summarized in Table 3. All models were statistically significant overall (all model P < .001). In the primary models adjusted for sex, age, and BMI, a 0.10 kg/kg higher relative HGS was associated with a 1.86 cm higher CMJ (95% CI: 0.73, 3.00; β = 0.247; partial R^2 = .116; P = .0015, P_{Holm} = .0046), a 0.107 s faster 20 m sprint (95% CI: 0.044, 0.169; β = -0.281; partial R^2 = .123; P = .0011, P_{Holm} = .0042), and 77.2 m greater YYIR1 distance (95% CI: 16.4, 138.1; β = 0.242; partial R^2 = .072; P = .0135, P_{Holm} = .0271). The T-test coefficient was not significant. Adding padel experience and weekly training volume in the extended models left the pattern and magnitude of the HGS coefficients materially unchanged.

Table 3. Primary and extended regression models for the association between relative handgrip strength and physical fitness.

Outcome	Model	HGS B [95% CI] per +0.10 kg/kg	β	partial R^2	model R^2	P / P_{Holm}
T-test time (s)	Primary	-0.160 [-0.423, +0.104]	-0.144	.017	.454	.231 / .231
T-test time (s)	Extended	-0.174 [-0.426, +0.079]	-0.157	.023	.512	.174 / .174
CMJ height (cm)	Primary	+1.865 [+0.734, +2.996]	+0.247	.116	.781	.0015 / .0046
CMJ height (cm)	Extended	+1.896 [+0.761, +3.031]	+0.252	.121	.786	.0013 / .0040
20 m sprint (s)	Primary	-0.107 [-0.169, -0.044]	-0.281	.123	.737	.0011 / .0042
20 m sprint (s)	Extended	-0.110 [-0.170, -0.049]	-0.288	.140	.761	<.001 / .0022
YYIR1 distance (m)	Primary	+77.2 [+16.4, +138.1]	+0.242	.072	.647	.0135 / .0271
YYIR1 distance (m)	Extended	+82.5 [+26.5, +138.5]	+0.258	.097	.709	.0044 / .0088

Note: Primary models include relative HGS, self-reported sex, age, and BMI. Extended models additionally include padel experience and weekly training volume. B is the unstandardized HGS coefficient expressed per +0.10 kg/kg relative HGS; β = standardized coefficient. Partial R^2 represents the proportion of residual outcome variance explained by HGS after accounting for the remaining model predictors. P / P_{Holm} gives the uncorrected and Holm-adjusted P values for the HGS coefficient within each four-outcome model family. Maximum VIF was 2.39 in the primary models and 2.63 in the extended models. HC3 robust-standard-error sensitivity checks did not change the inferential status of any HGS coefficient.

Formal HGS $\times$ sex interaction tests did not support robust effect modification. In the primary models, the interaction was non-significant for the T-test, CMJ, and YYIR1 (all $P \geq .408$); a nominal interaction was observed for sprint (P = .025), but it did not survive Holm correction across the four outcomes (P_{Holm} = .102) and was attenuated in the extended model (P = .069, P_{Holm} = .275). Pooled adjusted estimates were therefore retained. In body-size sensitivity analyses using absolute HGS with body mass, sex, and age as covariates, absolute HGS remained associated with CMJ, sprint, and YYIR1, but not T-test performance (Table 4), supporting the conclusion that the main pattern was not an artifact of ratio scaling. A secondary model using lean body mass yielded a similar pattern but showed greater multicollinearity (maximum VIF = 10.49) and was treated as supportive rather than primary.

Table 4. Sensitivity models using absolute handgrip strength with body-mass adjustment.

Outcome	Absolute HGS B [95% CI] per +1 kg	β	partial R^2	model R^2	P	P_{Holm}
T-test time (s)	-0.020 [-0.056, +0.016]	-0.210	.015	.453	.271	.271
CMJ height (cm)	+0.250 [+0.095, +0.405]	+0.386	.111	.780	.0019	.0077
20 m sprint (s)	-0.0129 [-0.0215, -0.0042]	-0.393	.096	.730	.0042	.0126
YYIR1 distance (m)	+10.2 [+1.9, +18.6]	+0.372	.067	.646	.0173	.0345

Note: Each model includes absolute HGS, self-reported sex, age, and body mass. B is the unstandardized HGS coefficient per +1 kg absolute HGS; β = standardized coefficient. Partial R^2 represents the proportion of residual outcome variance explained by HGS after accounting for the remaining covariates. P_{Holm} applies Holm correction across the four physical-fitness outcomes. Maximum VIF was 5.41, reflecting the expected shared variance between absolute HGS and body mass.

Phase Angle and Handgrip Strength

Phase angle was strongly correlated at the bivariate level with absolute HGS ($r = 0.77$, 95% CI: 0.67-0.85, $P < .001$) and relative HGS ($r = 0.75$, 95% CI: 0.65-0.83, $P < .001$). After controlling for sex, age, and BMI, the associations persisted for absolute HGS ($r_{\text{partial}} = 0.33$, 95% CI: 0.12-0.51, $P = .0019$, $P_{\text{Holm}} = .0019$) and relative HGS ($r_{\text{partial}} = 0.41$, 95% CI: 0.22-0.57, $P < .001$, $P_{\text{Holm}} < .001$). These relationships are included in Table 2 and shown as pooled data in Figure 2.

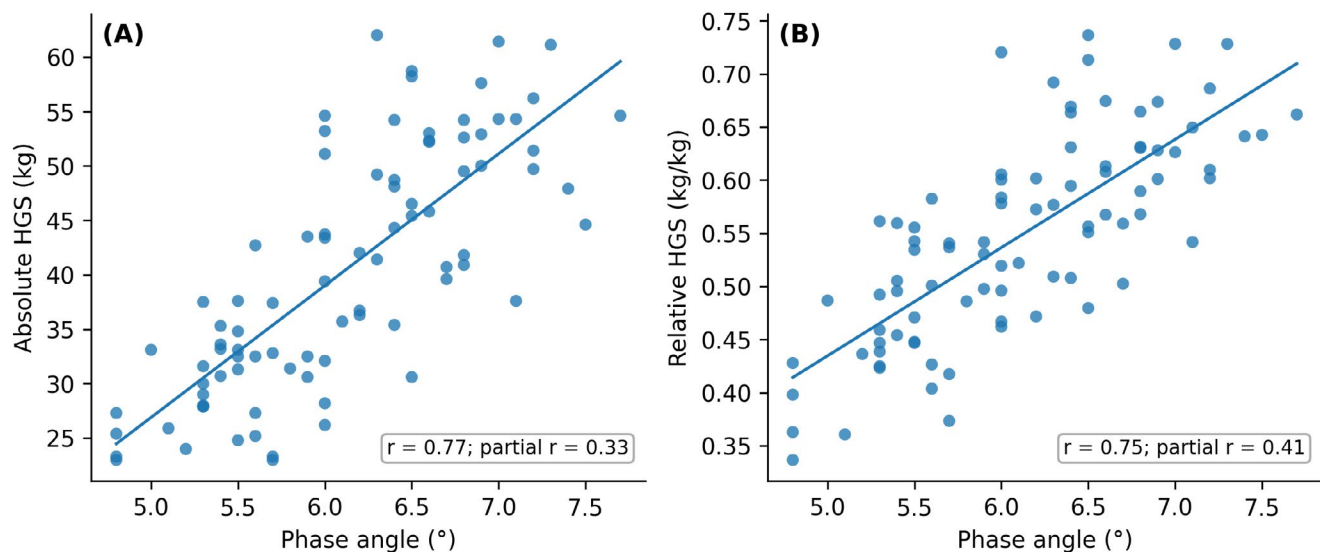


Figure 2. Pooled relationships between phase angle (°) and handgrip strength in 87 amateur padel players. (A) Absolute HGS (kg). (B) Relative HGS (kg/kg). Pearson bivariate r and r_{partial} controlling for self-reported sex, age, and BMI are displayed.

Padel Practice and Health-Related Quality of Life

Weekly padel training volume was positively associated with SF-36 PCS ($r = 0.33$, $P = .0021$, $P_{\text{Holm}} = .0043$) and MCS ($r = 0.32$, $P = .0028$, $P_{\text{Holm}} = .0043$). After adjustment for self-reported sex, age, and BMI, both associations remained modest but statistically significant after Holm correction across the two adjusted SF-36 summary-score associations (PCS: $r_{\text{partial}} = 0.28$, 95% CI: 0.07-0.47, $P = .0081$, $P_{\text{Holm}} = .0162$; MCS: $r_{\text{partial}} = 0.28$, 95% CI: 0.07-0.47, $P = .0086$, $P_{\text{Holm}} = .0162$). Figure 3 displays the pooled training-volume relationships with PCS and MCS.

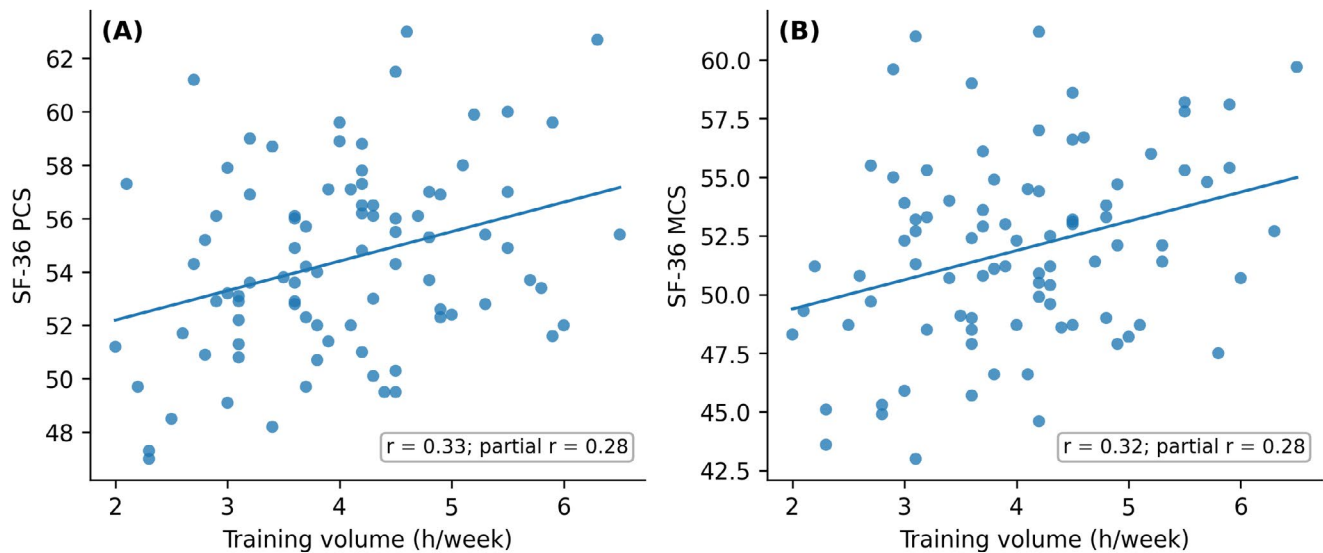


Figure 3. Pooled relationships between weekly padel training volume (hours/week) and SF-36 component summary scores in 87 amateur padel players. (A) Physical component summary (PCS). (B) Mental component summary (MCS). Pearson bivariate r and r_{partial} controlling for self-reported sex, age, and BMI are displayed.

Discussion

Relative HGS remained associated with CMJ height, 20 m sprint time, and YYIR1 distance after adjustment for sex, age, and BMI, whereas no adjusted association was observed for the pre-planned change-of-direction T-test. The same pattern was retained after adding padel experience and weekly training volume and in body-size sensitivity models based on absolute HGS. Formal HGS $\times$ sex testing did not identify robust effect modification after correction for multiple comparisons, supporting the use of pooled estimates. Phase angle was moderately associated with HGS after adjustment, and the exploratory analysis showed modest positive associations between weekly training volume and SF-36 physical and mental summary scores. These findings concern general physical fitness in amateur padel players; no padel-specific performance criterion was measured.

Handgrip Strength as an Indicator of Physical Fitness

The magnitude of HGS–performance associations varies across populations and testing methods, as summarized by Szaflik et al.¹⁵ In the present sample, the bivariate associations of absolute HGS with CMJ height ($r = 0.82$) and 20 m sprint time ($r = -0.80$) were stronger in magnitude than the corresponding correlations reported by Martín Simón and Rojano Ortega ($r = 0.588$ and $r = -0.536$, respectively) in a mixed-sex cohort of Physical Education students.¹⁸ Sustained padel participation may select for or reinforce a broader fitness profile in which gripping capacity covaries with lower-limb power, speed, and intermittent endurance. Repeated racket handling may also contribute to sport-related grip adaptations. However, the cross-sectional design cannot determine whether padel participation contributed to the observed covariance or whether individuals with higher overall fitness were more likely to engage regularly in padel.

Adjustment for sex, age, and BMI substantially attenuated the bivariate associations, indicating that part of the shared variance between HGS and physical-fitness outcomes was accounted for by these covariates. Sex-related differences in body composition are well established.⁴¹ The present

multivariable models do not permit the attenuation to be attributed to any single covariate. The adjusted regression coefficients nevertheless indicated that, in the primary models, a 0.10 kg/kg higher relative HGS was associated with approximately 1.9 cm greater CMJ height, 0.11 s faster sprint time, and 77 m greater YYIR1 distance. The partial R^2 for HGS was approximately .12 for CMJ and sprint and .07 for YYIR1. These findings represent associations and should not be interpreted as evidence that increasing grip strength would cause improvements in lower-limb performance.

The lack of an adjusted association with T-test time adds specificity to the pattern. The T-test is a pre-planned change-of-direction task requiring acceleration, deceleration, lateral displacement, braking, and directional transitions.³⁸ Because the movement sequence is known in advance and does not require a response to an external stimulus, it should be interpreted as a measure of change-of-direction performance rather than reactive agility.⁴² Its performance therefore reflects a combination of force production, braking capacity, movement technique, and coordination that may be less closely represented by a general strength marker such as HGS.

The body-size sensitivity analysis further supports the robustness of the central result. When absolute HGS was modeled together with body mass, sex, and age, the associations with CMJ, sprint, and YYIR1 remained significant after Holm correction, whereas the T-test association remained non-significant. Thus, the principal pattern did not depend solely on expressing HGS as a ratio to body mass. A secondary analysis using lean body mass was directionally similar but generated higher multicollinearity, consistent with the substantial shared variance among sex, lean mass, and absolute HGS; those estimates should therefore be considered supportive rather than definitive.

Phase Angle and Handgrip Strength

The strong bivariate association between phase angle and absolute HGS ($r = 0.77$) is consistent with reports in physically active adults and athletes, including resistance-trained participants and elite female volleyball players.^{21,24} The present findings extend this evidence to amateur padel players: after adjustment for sex, age, and BMI, phase angle remained moderately associated with both absolute and relative HGS, with the larger adjusted coefficient observed for relative HGS. Because the study is cross-sectional, this result should be interpreted as shared physiological variation rather than evidence that phase angle determines strength or training adaptation.

Phase angle integrates the relationship between reactance and resistance and is commonly interpreted as a marker related to cell membrane properties and body-cell mass.^{19,20} In this context, its association with HGS may provide information complementary to a simple force measure. The data do not establish phase angle as a monitoring biomarker for padel: whether within-person changes in phase angle track changes in muscular function, training status, or performance requires repeated longitudinal assessment.

Padel Practice and Quality of Life

Padel-specific evidence on health-related quality of life remains limited, with existing work more often addressing psychological constructs linked to performance than broad health status.²⁸ In the present exploratory analysis, greater weekly training volume was modestly associated with higher PCS and MCS values, and the associations remained significant after adjustment for sex, age, and BMI and after Holm correction across PCS and MCS. The magnitude was small to

moderate, and the cross-sectional design leaves directionality unresolved; individuals with better perceived health may simply participate more often.

The direction of these associations is compatible with broader evidence linking sport participation to physical, psychological, and social benefits and with epidemiological observations for racket sports.²⁵⁻²⁷ Padel is predominantly played in doubles, so its social format may plausibly contribute to perceived wellbeing. That mechanism remains speculative because social interaction, social support, and motives for participation were not directly measured. The social dimension is nevertheless a relevant hypothesis for future padel-specific health research using longitudinal, qualitative, or mixed-method designs.

From an applied perspective, the present findings support HGS as a candidate low-cost marker for further validation, not as a stand-alone screening test for padel performance. Before routine use can be recommended, relative or absolute HGS should be tested prospectively against padel-specific criteria such as stroke velocity, technical accuracy, and on-court movement performance. Likewise, phase angle may warrant longitudinal study as a complementary physiological measure, but the current data do not establish responsiveness to training or prognostic value.

The correlational nature of the data therefore imposes firm limits on practical recommendations. The associations indicate that HGS captures variance shared with several general fitness qualities in amateur padel players, but they do not show that targeted grip-strength training would improve jump, sprint, or intermittent-endurance performance.

The exploratory quality-of-life result may also be relevant to public-health research because padel combines repeated physical activity with a structured social setting. However, intervention studies are required to establish whether increasing padel participation improves health-related quality of life and to identify the dose, participant characteristics, and contextual factors that might moderate any effect.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference for all three aims. Longitudinal and intervention studies are required to determine whether within-person changes in HGS or phase angle correspond to changes in physical fitness and whether padel participation itself influences health-related quality of life.

Second, although the sample exceeded the a priori requirement for the primary correlation analysis and the multivariable models were kept parsimonious relative to the available sample, it was a convenience sample of amateur players from Northern Italy. The study was not powered for inferential comparisons between sexes. Replication in larger, geographically diverse samples across competitive levels and age strata is warranted.

Third, adjustment was limited to measured covariates. Sex, age, and BMI were included consistently in the primary analyses, with padel experience and training volume added in extended models, but nutrition, habitual activity outside padel, sleep, injury history, genetic factors, and other potential confounders were not comprehensively assessed.

Fourth, no padel-specific performance criterion was included. The T-test, CMJ, 20 m sprint, and YYIR1 characterize general change-of-direction, power, speed, and intermittent-endurance capacities, respectively; they do not quantify stroke velocity, shot accuracy, decision-making, or

competitive match performance. Accordingly, the present results should not be generalized from physical fitness to padel-specific performance.

Fifth, the quality-of-life aim was exploratory and focused on the PCS and MCS summary scores. Accordingly, these findings should be considered hypothesis-generating and require confirmation in prospectively designed studies.

Sixth, although the Italian SF-36 has established reliability and validity, it is a generic health-status instrument. Padel-specific measures of social experience, enjoyment, motivation, and perceived participation benefits could be more sensitive to mechanisms unique to this sport.

Finally, study-specific intra-session reliability was available for the multi-trial HGS, CMJ, sprint, and T-test assessments, but the YYIR1 was administered once and study-specific reliability could not be estimated. Between-day reliability was not assessed for any field test, so measurement error across sessions remains unknown.

In summary, relative HGS was associated with CMJ height, 20 m sprint time, and YYIR1 distance after adjustment for sex, age, and BMI in amateur padel players, whereas no adjusted association was observed for the pre-planned change-of-direction T-test. The pattern was stable in extended regression models and in body-size sensitivity analyses using absolute HGS, and there was no robust evidence of HGS $\times$ sex effect modification after correction for multiple testing. Phase angle showed a complementary adjusted association with HGS. Weekly padel training volume was modestly associated with SF-36 physical and mental summary scores in exploratory analyses. These findings identify cross-sectional correlates of general physical fitness and perceived health in amateur padel players; prospective studies with padel-specific performance outcomes are needed before causal, prognostic, or screening interpretations are warranted.

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Conflict of Interest

The authors declare no conflict of interest.

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Statement on the Use of Artificial Intelligence

No generative AI or large language model was used in the conceptual development, data analysis, or interpretation of this work. Minor editorial refinements were made using DeepL assisted tools strictly for linguistic clarity. The authors retain full responsibility for the content.

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