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IMPROVING THE TRAINING SYSTEM OF HIGHLY QUALIFIED PARA-ATHLETES IN PARA-ATHLETICS: A CASE STUDY OF T46 CATEGORY RUNNING DISCIPLINES

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ABOUT ARTICLE

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Abstract: This study investigates the improvement of the training system for highly qualified para-athletes competing in T46 category running disciplines within para-athletics. The T46 classification encompasses athletes with upper limb amputation or equivalent impairment who compete in sprint and middle-distance track events using a running prosthesis. A pedagogical experiment was conducted across the 2023–2024 training year involving a control group (n=10) and an experimental group (n=10). Baseline anthropometric measurements — height, weight, leg length, arm length, and residual limb length — and six standardised physical fitness tests revealed no statistically significant intergroup differences ($p>0.05$), confirming the homogeneity of the experimental cohorts. Functional state monitoring using heart-rate telemetry and estimated maximal oxygen uptake (VO_{2max}) assessment provided individual physiological profiles that informed the individualisation of training prescriptions. A three-block specialised exercise complex was developed and applied exclusively to the experimental group: Block I targeting start

mechanics and acceleration over 0–30 m; Block II targeting speed-endurance and running economy over 60–200 m; and Block III targeting prosthesis adaptation and residual limb conditioning. The exercise complex was embedded within an annual periodisation plan comprising five macro-periods: general preparatory, special preparatory, pre-competition, competition, and transition. Post-intervention testing demonstrated statistically significant improvements in the experimental group relative to the control group across all performance indicators, including 60 m sprint ($p<0.05$), 100 m sprint ($p<0.01$), 200 m sprint ($p<0.01$), standing long jump ($p<0.05$), triple jump ($p<0.05$), and push-up endurance ($p<0.01$). These findings confirm that a structured, periodised, and prosthesis-adapted training methodology produces superior performance outcomes in elite T46 para-athletes compared to conventional training approaches.

Introduction. Para-athletics competitive track and field sport for athletes with physical, visual, and intellectual impairments has witnessed remarkable performance advancement over the past two decades, driven by improvements in prosthetic technology, training science, and athlete classification systems [1]. Among the various functional classifications, the T46 category encompasses athletes with unilateral below-elbow amputation or analogous upper-limb impairment who compete in sprint and middle-distance running events. Although the primary propulsive mechanism in running is generated by the lower limbs, upper-limb asymmetry in T46 athletes introduces distinctive biomechanical challenges: altered arm-swing dynamics, compensatory trunk rotation patterns, and modified neuromuscular coordination strategies that differentiate T46 performance from both able-bodied athletics and lower-limb amputee categories (T61–T64) [2].

The scientific literature on systematic training methodology for T46 athletes remains comparatively sparse relative to the broader Paralympic sport science literature. While a growing body of research addresses sprint biomechanics [3], prosthetic blade technology [4], and classification criteria [5] in lower-limb amputee athletes, evidence-based periodisation models and specialised exercise prescriptions specifically designed for upper-limb amputee runners are less well developed. Coaching practice in this category frequently involves direct

adaptation of able-bodied sprint training models without sufficient consideration of the unique physiological, biomechanical, and prosthetic-adaptation demands of T46 competition [6].

A particularly underexplored dimension is the interaction between residual limb conditioning, prosthesis socket fit, and training load management. Unlike lower-limb prosthetic running, where the running blade directly transmits propulsive forces, upper-limb prostheses in T46 running primarily contribute to dynamic balance and rhythmic coordination. Nevertheless, prolonged high-intensity training generates cumulative mechanical stress at the skin-socket interface, and inadequate attention to residual limb conditioning can lead to dermatological complications that interrupt training continuity [7]. Systematic inclusion of prosthesis adaptation protocols within the annual training plan is therefore a prerequisite for sustained performance development.

The present study was designed to address these gaps by developing and empirically evaluating a comprehensive annual training system for highly qualified T46 para-athletes. The system integrates biomechanically informed technical drills, periodised physical conditioning, and structured prosthesis adaptation protocols. A pedagogical experiment with parallel control and experimental groups was employed to test the hypothesis that athletes following the developed methodology would demonstrate significantly greater performance improvements over one training year compared to athletes following a standard training programme.

The study addresses three primary objectives: (1) to confirm the baseline equivalence of control and experimental groups on anthropometric and physical fitness measures; (2) to profile the functional states of experimental group athletes using physiological monitoring technology; and (3) to evaluate the effectiveness of the developed training methodology by comparing pre-to-post performance changes between groups.

Methods. Study Design and Participants

A one-year controlled pedagogical experiment was conducted from September 2023 to August 2024 at the Paralympic sports training centre of the Uzbekistan State University of Physical Culture and Sports. Twenty male T46-classified para-athletes (mean age 21.8 ± 1.3 years) were recruited and randomly allocated to a control group ($n=10$) or an experimental group ($n=10$). All participants held active T46 classification certificates issued by World Para Athletics. Inclusion criteria were: active competition status, minimum three years of systematic para-athletics training, no acute musculoskeletal injury in the six months preceding enrolment, and access to a certified carbon-fibre running prosthesis. Exclusion criteria included re-classification during the study period and voluntary withdrawal.

Both groups trained under the same head coach, in the same facility, for the same total weekly training volume. The experimental group received the newly developed training methodology — including the three-block specialised exercise complex and the structured annual periodisation plan — while the control group followed the standard nationally prescribed para-athletics training curriculum. The coach was informed of group allocation but blinded to the specific exercise content of the experimental protocol beyond what was necessary for safe administration.

Ethical approval was obtained from the institutional ethics committee. Written informed consent was obtained from all participants. Data were anonymised using an initial-and-family-name coding system (e.g., A-ov K.) throughout data collection and reporting.

Anthropometric Assessment

Anthropometric measurements were recorded at baseline (September 2023) and follow-up (August 2024). Measured parameters included: standing height (cm), body mass (kg), functional leg length measured from greater trochanter to lateral malleolus (cm), dominant arm length measured from acromion to distal phalanx tip (cm), and residual limb length measured from the acromion to the distal end of the residual humerus or radius (cm). All measurements were taken in the morning in a fasted state by the same trained assessor using calibrated anthropometric instruments.

Physical Fitness Assessment

Six standardised physical fitness tests were administered at three time points: baseline (September 2023), mid-year checkpoint (March 2024), and post-intervention (August 2024): (1) 60 m sprint from a standing start (seconds); (2) 100 m sprint from a standing start (seconds); (3) 200 m sprint from a rolling start (seconds); (4) Standing long jump with prosthesis fitted (cm); (5) Triple hop for distance starting from intact limb (cm); and (6) Maximum push-up repetitions in 60 seconds. All sprint tests were conducted on a World Athletics-certified synthetic track under standardised meteorological conditions (wind speed < 2.0 m/s). Timing was recorded using dual-beam electronic timing gates (Brower TC System).

Functional State Monitoring

During a representative baseline training session, each experimental group athlete was fitted with a heart-rate monitoring belt (Polar H10) recording beat-to-beat R-R interval data. Data were subsequently analysed to extract resting HR (HR_{rest}), average training HR (HR_{avg}), maximum HR (HR_{max}), training impulse score (TRIMP, calculated using Banister's method), total caloric expenditure (kcal), and estimated VO₂max using the Uth-Sørensen-

Overgaard-Pedersen formula. These data were used to compute individual training intensity zones and to calibrate the exercise prescriptions within the developed methodology.

Statistical Analysis

Descriptive statistics (mean M , standard deviation σ , coefficient of variation $V\%$) were computed for all variables. Baseline group equivalence was assessed using independent-samples t-tests. Within-group pre-to-post changes were evaluated using paired t-tests. Between-group post-intervention differences were assessed using independent-samples t-tests and effect size estimates (Cohen's d). A significance level of $\alpha=0.05$ was applied throughout. Statistical analyses were performed using IBM SPSS Statistics v.26 (IBM Corp., Armonk, NY).

Results and discussion. Baseline Anthropometric Characteristics

Tables 1 and 2 present the individual and group-level baseline anthropometric data for the control and experimental groups respectively.

Table 1. Baseline anthropometric characteristics Control group (n=10)

No	Athlete	Age (yrs)	Height (cm)	Weight (kg)	Leg length (cm)	Arm length (cm)	Residual limb (cm)
1	K-ov A.	22	172	68	88	74	28
2	T-ev B.	20	169	65	86	72	25
3	M-ov S.	23	175	71	91	76	30
4	U-ev D.	21	168	63	87	73	27
5	R-ov E.	24	177	74	92	77	31
6	S-ov F.	22	170	66	88	74	26
7	N-ev G.	20	166	62	85	71	24
8	O-ov H.	23	174	70	90	75	29
9	P-ev I.	21	171	67	89	74	28
10	Q-ov J.	22	173	69	90	75	29
	M$\pm\sigma$	21.8 \pm 1.2	171.5 \pm 3.2	67.5 \pm 3.6	88.6 \pm 2.1	74.1 \pm 1.8	27.7 \pm 2.0
	V (%)	5.5	1.9	5.3	2.4	2.4	7.2

The control group exhibited mean values of: height 171.5 \pm 3.2 cm, body mass 67.5 \pm 3.6 kg, leg length 88.6 \pm 2.1 cm, arm length 74.1 \pm 1.8 cm, and residual limb length 27.7 \pm 2.0 cm. The comparatively low coefficients of variation for height (1.9%), leg length (2.4%), and arm length (2.4%) reflect the relatively homogeneous morphological profile of specialised T46

sprinters. The higher V% for residual limb length (7.2%) is consistent with the natural variation in amputation level within the T46 classification band.

Table 2. Baseline anthropometric characteristics — Experimental group (n=10)

No	Athlete	Age (yrs)	Height (cm)	Weight (kg)	Leg length (cm)	Arm length (cm)	Residual limb (cm)
1	A-ov K.	22	173	69	89	75	29
2	B-ev L.	21	170	66	87	73	26
3	C-ov M.	23	176	72	92	77	31
4	D-ev N.	20	167	63	86	72	24
5	E-ov O.	24	178	75	93	78	32
6	F-ev P.	22	171	67	88	74	27
7	G-ov Q.	20	165	61	84	70	23
8	H-ev R.	23	174	70	90	75	29
9	I-ov S.	21	172	68	89	74	28
10	J-ev T.	22	174	70	91	76	30
M±σ		21.8±1.3	172.0±3.6	68.1±3.9	88.9±2.4	74.4±2.0	27.9±2.5
V (%)		6.0	2.1	5.7	2.7	2.7	9.0

The experimental group demonstrated mean values of: height 172.0 ± 3.6 cm, body mass 68.1 ± 3.9 kg, leg length 88.9 ± 2.4 cm, arm length 74.4 ± 2.0 cm, and residual limb length 27.9 ± 2.5 cm. The patterns of variation were comparable to those observed in the control group. Table 3 provides the direct between-group statistical comparison.

Table 3. Comparative baseline anthropometric characteristics both groups (n=20)

No	Indicator	Exp. group M±σ	V (%)	Con. group M±σ	V (%)	p	Interpretation
1	Height (cm)	172.0 ± 3.6	2.1	171.5 ± 3.2	1.9	>0.05	No significant difference
2	Weight (kg)	68.1 ± 3.9	5.7	67.5 ± 3.6	5.3	>0.05	No significant difference
3	Leg length (cm)	88.9 ± 2.4	2.7	88.6 ± 2.1	2.4	>0.05	No significant difference
4	Arm length (cm)	74.4 ± 2.0	2.7	74.1 ± 1.8	2.4	>0.05	No significant difference
5	Residual limb (cm)	27.9 ± 2.5	9.0	27.7 ± 2.0	7.2	>0.05	No significant difference

Independent-samples t-tests confirmed no statistically significant differences between groups on any anthropometric variable ($p>0.05$ for all five measures). The largest absolute difference was observed for height (0.5 cm), while the residual limb length difference (0.2 cm) was negligible. These findings establish that the two groups were morphologically equivalent at the outset of the experiment, satisfying a fundamental prerequisite for valid between-group experimental comparison. The equivalence of residual limb length is particularly important, as this parameter significantly influences socket fit quality and biomechanical prosthesis function during sprinting [8].

Baseline Physical Fitness Characteristics

Tables 4 and 5 present the baseline physical fitness test results for the experimental and control groups respectively, with Table 6 providing the comparative statistical analysis.

Table 4. Baseline physical fitness indicators Experimental group (n=10)

No	Athlete	60 m (sec)	100 m (sec)	200 m (sec)	Standing long jump (cm)	Triple jump (cm)	Push-up (reps)
1	A-ov K.	8.12	13.45	27.80	198	510	32
2	B-ev L.	8.34	13.78	28.20	192	498	29
3	C-ov M.	7.98	13.21	27.40	205	525	35
4	D-ev N.	8.56	14.02	28.70	188	490	27
5	E-ov O.	7.85	13.10	27.10	210	535	37
6	F-ev P.	8.22	13.60	27.95	196	508	31
7	G-ov Q.	8.67	14.15	29.00	185	482	26
8	H-ev R.	8.05	13.35	27.60	202	518	33
9	I-ov S.	8.41	13.88	28.40	190	495	28
10	J-ev T.	8.18	13.50	27.75	199	512	32
	M±σ	8.24 ± 0.26	13.60 ± 0.31	27.99 ± 0.56	196.5 ± 7.6	507.3 ± 15.9	31.0 ± 3.3
	V (%)	3.16	2.28	2.00	3.87	3.13	10.65

Table 5. Baseline physical fitness indicators — Control group (n=10)

No	Athlete	60 m (sec)	100 m (sec)	200 m (sec)	Standing long jump (cm)	Triple jump (cm)	Push-up (reps)
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1	K-ov A.	8.18	13.52	27.90	196	507	31
2	T-ev B.	8.40	13.85	28.30	191	495	28
3	M-ov S.	8.02	13.28	27.50	204	522	34
4	U-ev D.	8.62	14.10	28.80	187	488	26
5	R-ov E.	7.90	13.18	27.20	208	532	36
6	S-ov F.	8.28	13.68	28.05	195	505	30
7	N-ev G.	8.72	14.22	29.10	184	480	25
8	O-ov H.	8.10	13.42	27.70	201	515	32
9	P-ev I.	8.48	13.95	28.50	189	492	27
10	Q-ov J.	8.24	13.58	27.85	198	510	31
M±σ		8.29 ± 0.27	13.68 ± 0.32	28.09 ± 0.57	195.3 ± 7.5	504.6 ± 16.2	30.0 ± 3.4
V (%)		3.26	2.34	2.03	3.84	3.21	11.33

Table 6. Comparative baseline physical fitness indicators — both groups (n=20)

No	Test	Exp. group M±σ	V (%)	Con. group M±σ	V (%)	t	p
1	60 m sprint (sec)	8.24 ± 0.26	3.16	8.29 ± 0.27	3.26	0.41	>0.05
2	100 m sprint (sec)	13.60 ± 0.31	2.28	13.68 ± 0.32	2.34	0.56	>0.05
3	200 m sprint (sec)	27.99 ± 0.56	2.00	28.09 ± 0.57	2.03	0.39	>0.05
4	Standing long jump (cm)	196.5 ± 7.6	3.87	195.3 ± 7.5	3.84	0.35	>0.05
5	Triple jump (cm)	507.3 ± 15.9	3.13	504.6 ± 16.2	3.21	0.37	>0.05
6	Push-up (reps)	31.0 ± 3.3	10.65	30.0 ± 3.4	11.33	0.67	>0.05

No statistically significant between-group differences were identified for any of the six physical fitness tests at baseline (t-values ranging from 0.35 to 0.67; all p>0.05). The experimental group's mean 60 m time was 8.24 ± 0.26 sec compared to 8.29 ± 0.27 sec for the control group; 100 m times were 13.60 ± 0.31 vs. 13.68 ± 0.32 sec; 200 m times were 27.99 ± 0.56 vs. 28.09 ± 0.57 sec; standing long jump was 196.5 ± 7.6 vs. 195.3 ± 7.5 cm; triple jump was 507.3 ± 15.9 vs. 504.6 ± 16.2 cm; and push-up reps were 31.0 ± 3.3 vs. 30.0 ± 3.4.

The similarity of performance levels across all six tests, combined with the anthropometric equivalence established in Section 3.1, provides strong empirical justification

for attributing any subsequent between-group performance differences to the differential training methodology rather than to pre-existing physical characteristics. The coefficients of variation for sprint tests (2.0–3.3%) reflect the relatively homogeneous performance levels expected in national-level para-athletics squads, while the higher V% for push-up repetitions (10.65–11.33%) reflects the greater inter-individual variability typical of upper-body strength measures in this population [9].

Functional State Monitoring

Table 7 summarises the functional load parameters recorded for six experimental group athletes during the standardised baseline monitoring session.

Table 7. Functional load characteristics of monitored athletes (baseline training session)

Athlete	Duration	TRIMP	Kcal	HR rest	HR avg	HR max	VO2max (est.)	Aerob / Anaerob
A-ov K. (22y)	1h 45m	62	580	58	142	188	52.4	3.1 / 2.8
B-ev L. (21y)	1h 38m	57	540	61	138	184	51.0	2.9 / 2.4
C-ov M. (23y)	1h 50m	68	620	55	148	192	54.1	3.4 / 3.1
D-ev N. (20y)	1h 30m	51	490	63	132	180	49.5	2.6 / 2.0
E-ov O. (24y)	1h 55m	72	650	53	151	196	55.8	3.6 / 3.4
F-ev P. (22y)	1h 42m	59	558	60	140	186	51.8	3.0 / 2.6

The monitoring session was structured as follows: 10-minute dynamic warm-up including joint rotations, progressive stride drills, and prosthesis-specific alignment checks; 15 minutes of start-block practice and 30 m acceleration runs; three 12-minute blocks of sprint, jump, and strength exercises with 90-second active rest between exercises; a 400 m time trial; and a 10-minute cool-down including static stretching and prosthesis socket inspection.

TRIMP values ranged from 51 (D-ev N., age 20) to 72 (E-ov O., age 24), reflecting meaningful individual variation in training impulse uptake despite nominally identical external loads. HR_max values ranged from 180 to 196 bpm, corresponding to age-predicted maxima of 200 and 196 bpm respectively, indicating that all athletes were capable of reaching near-maximal cardiovascular exertion during the sprint components of the session. Estimated

VO2max values ranged from 49.5 to 55.8 ml/kg/min, which is consistent with the aerobic capacity profiles documented for elite able-bodied sprint athletes and suggests that the T46 athletes in this study possess competitive cardiorespiratory fitness [10].

The aerobic-to-anaerobic load ratio showed the expected variation across exercise blocks, with higher anaerobic contributions recorded for sprint-dominant athletes (E-ov O.: 3.6/3.4) and more balanced aerobic-anaerobic profiles for athletes with stronger endurance backgrounds (B-ev L.: 2.9/2.4). These individual profiles informed the individualisation of exercise prescription intensity targets within the developed methodology, with athletes demonstrating higher aerobic capacity receiving proportionally greater sprint volume and athletes with lower TRIMP scores being assigned increased intensity loads to stimulate physiological adaptation.

Developed Methodology: Annual Periodisation Plan

The developed training system was organised according to a hierarchical periodisation structure encompassing five macro-periods across the 52-week training year. Table 8 presents the annual periodisation plan.

Table 8. Annual periodisation plan for T46 para-athletics running disciplines

Period	Mesocycle focus	Duration (wk)	Sessions/wk	Volume (km/wk)	Intensity zone (%HRmax)	Key methods
Preparatory I (General)	Aerobic base & strength	6	5-6	40-55	60-75%	Continuous running, circuit strength, prosthesis adaptation drills
Preparatory II (Special)	Speed-endurance & technique	8	6	55-70	75-88%	Interval training, sprint-float-sprint, start drills, residual limb loading
Pre-competition	Race-specific prep	4	5-6	45-60	80-92%	Competitive simulation, time trials,

						technical refinement
Competition	Performance realisation	16	4-5	30-45	85-100%	Race participation, taper cycles, recovery microcycles
Transition	Active recovery	4	3	15-25	55-65%	Active rest, swimming/cycling, prosthesis maintenance, psychological reset

The General Preparatory Period (6 weeks) focused on developing the aerobic base, general strength, and introducing systematic prosthesis adaptation protocols. Weekly running volume ranged from 40 to 55 km at 60–75% HR_{max} intensity. Circuit strength training targeting the posterior chain, hip flexors, and core stabilisers was conducted three times per week. Prosthesis-specific sessions included socket fit assessment, blade stiffness calibration, and progressive load exposure to the residual limb skin-socket interface.

The Special Preparatory Period (8 weeks) introduced speed-endurance and technical specificity. Sprint-float-sprint intervals, standing-start block drills, and bounding sequences were incorporated. Running volume increased to 55–70 km/week while intensity shifted toward the 75–88% HR_{max} zone. Residual limb conditioning exercises progressed from standing static loading to dynamic prosthetic blade propulsion patterns.

The Pre-Competition Period (4 weeks) emphasised race-specific preparation including time trials, competitive simulation sessions, and technical refinement under near-race conditions. Volume was reduced to 45–60 km/week while intensity peaked at 80–92% HR_{max} to sharpen speed and ensure metabolic readiness for competition.

The Competition Period (16 weeks) centred on performance realisation. Training adopted a wave-periodisation structure with alternating high-intensity competition microcycles and lower-intensity recovery microcycles. Volume was reduced to 30–45 km/week. Post-competition prosthesis inspection and residual limb care were standardised components of the recovery protocol following each competitive event.

The Transition Period (4 weeks) provided active recovery through cross-training (swimming, cycling) at 55–65% HR_{max}, psychological reset sessions with a sports psychologist, and comprehensive prosthesis maintenance including socket replacement assessment and blade inspection.

Three-Block Specialised Exercise Complex

A three-block specialised exercise complex was developed as the core technical-conditioning component of the experimental methodology. Table 9 presents the complete exercise complex with prescribed loads, rest periods, heart-rate targets, and training focus descriptors.

Table 9. Three-block specialised exercise complex for T46 para-athletes

No	Exercise content	Sets × Reps / Duration	Rest	HR target (bpm)	Zone	Focus
BLOCK I — Start mechanics and acceleration (0–30 m)						
1	Stationary start from blocks with prosthetic blade — 3-point position × 10 m	6×10 m	90 sec	< 140	I–II	Start reaction & stride initialisation
2	Flying start acceleration 20–30 m: stride length progressively increases	5×30 m	2 min	140–160	II–III	Acceleration mechanics
3	Contrast drill: slow walk 10 m → explosive sprint 20 m	4×30 m	2 min	150–170	III	Neuromuscular contrast activation
4	Bounding (scissor jumps) over low hurdles × 6 hurdles, 0.5 m spacing	4 sets	90 sec	130–150	II	Ground contact time reduction
5	Uphill acceleration 15 m (3–5° incline)	6 reps	2 min	155–175	III	Power output & posterior chain loading
BLOCK II — Speed-endurance and running economy (60–200 m)						
6	60 m time trial: 3 attempts with full recovery	3×60 m	5 min	> 175	IV–V	Maximum velocity application

7	Sprint-float-sprint: 30 m sprint → 20 m float → 30 m sprint	4 reps	4 min	165–185	IV	Speed maintenance under fatigue
8	Interval 100 m × 6 at 85–90% intensity, 90-sec active rest	6×100 m	90 sec	160–180	IV	Speed endurance
9	200 m time trial at race pace + 5%	2 reps	6 min	170–190	IV–V	Race-specific conditioning
10	Relaxed stride drills: 80 m high-knee drill → 80 m butt-kick → 80 m straight-leg	3 sets	3 min	120–140	I–II	Running economy & technique
BLOCK III — Prosthesis adaptation and residual limb conditioning						
11	Residual limb socket pressure tolerance: 15 min standing load progression	15 min	—	< 120	I	Skin-socket interface conditioning
12	Unilateral leg press (intact limb) 3×12 → bilateral press with prosthetic blade 3×8	3×12 / 3×8	90 sec	< 140	I–II	Limb symmetry & stump strength
13	Balance board single-leg stance on prosthetic limb: 3×45 sec	3×45 sec	60 sec	< 130	I	Proprioceptive adaptation
14	Prosthetic blade replacement & fit check: standardised protocol post each session	Post-session	—	—	—	Equipment maintenance & safety

Block I — Start Mechanics and Acceleration (0–30 m): This block targeted the most technically critical phase of sprint performance in T46 athletes. Prosthetic blade runners typically demonstrate a delayed acceleration profile compared to able-bodied sprinters due to the reduced neuromuscular proprioceptive feedback from the prosthetic limb [11]. Stationary block starts from a 3-point position, flying-start accelerations, contrast drills (slow walk to explosive sprint), bounding sequences, and uphill acceleration runs were prescribed at 4–6 sets with 90-second to 2-minute recovery. Heart-rate targets of 140–175 bpm (Zones II–III) ensured sufficient neuromuscular activation without excessive metabolic fatigue that could compromise technical execution quality.

Block II — Speed-Endurance and Running Economy (60–200 m): This block addressed the physiological demands of T46 competition across sprint distances from 60 to 200 m. The sprint-float-sprint protocol (30 m sprint → 20 m relaxed float → 30 m sprint) was particularly effective in developing the ability to maintain mechanical efficiency during the deceleration phase that characterises competition performance in this classification. Interval 100 m repetitions at 85–90% intensity and 200 m time trials at race pace were employed to develop the specific endurance capacity required for the 100 m and 200 m T46 events. Heart-rate targets of 160–190 bpm (Zones III–V) reflected the near-maximal intensity demands of these exercises.

Block III — Prosthesis Adaptation and Residual Limb Conditioning: This block represents the most distinctive feature of the developed methodology relative to conventional sprint training programmes. Three exercises specifically addressed the prosthesis-athlete interface: (a) progressive residual limb socket pressure tolerance training using 15-minute standing load progressions; (b) unilateral and bilateral leg press work with the running blade fitted to develop stump strength and limb symmetry; and (c) single-leg balance board training on the prosthetic limb to enhance proprioceptive adaptation and socket suspension. Additionally, a standardised post-session prosthetic blade replacement and fit-check protocol was implemented to ensure consistent equipment condition across all training sessions.

Post-Intervention Performance Outcomes

Table 10 presents the post-intervention physical fitness test results and between-group comparison statistics following one year of implementation of the experimental methodology.

Table 10. Post-intervention physical fitness comparison — both groups (n=20)

No	Test	Exp. group M±σ	V (%)	Con. group M±σ	V (%)	t	p
1	60 m sprint (sec)	7.84 ± 0.21	2.68	8.11 ± 0.25	3.08	2.62	<0.05
2	100 m sprint (sec)	12.98 ± 0.27	2.08	13.41 ± 0.30	2.24	3.36	<0.01
3	200 m sprint (sec)	26.87 ± 0.48	1.79	27.72 ± 0.53	1.91	3.74	<0.01
4	Standing long jump (cm)	208.4 ± 6.8	3.26	199.1 ± 7.2	3.62	2.97	<0.05
5	Triple jump (cm)	528.6 ± 13.4	2.54	511.8 ± 15.1	2.95	2.63	<0.05

6	Push-up (reps)	38.2 ± 3.0	7.85	32.4 ± 3.2	9.88	4.15	<0.01
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Statistically significant between-group differences in favour of the experimental group were observed for all six performance tests at the end of the study year. The most pronounced improvements were recorded for the 100 m sprint (experimental group: 12.98 ± 0.27 sec vs. control: 13.41 ± 0.30 sec; $t=3.36$, $p<0.01$), the 200 m sprint (26.87 ± 0.48 vs. 27.72 ± 0.53 sec; $t=3.74$, $p<0.01$), and push-up endurance (38.2 ± 3.0 vs. 32.4 ± 3.2 reps; $t=4.15$, $p<0.01$). Significant differences were also found for the 60 m sprint (7.84 ± 0.21 vs. 8.11 ± 0.25 sec; $t=2.62$, $p<0.05$), standing long jump (208.4 ± 6.8 vs. 199.1 ± 7.2 cm; $t=2.97$, $p<0.05$), and triple jump (528.6 ± 13.4 vs. 511.8 ± 15.1 cm; $t=2.63$, $p<0.05$).

Within-group analysis revealed that the experimental group's mean 100 m time improved by 0.62 seconds (4.56%) from baseline to post-intervention, while the control group improved by only 0.27 seconds (1.97%) over the same period. For the 200 m, the experimental group improved by 1.12 seconds (4.00%) compared to 0.37 seconds (1.32%) for the control group. These differences represent practically meaningful performance margins in elite para-athletics competition, where the gap between Paralympic qualification standards and world-record performances in T46 typically spans less than three seconds across all sprint distances.

Discussion. The present findings provide strong empirical support for the hypothesis that a structured, periodised, and prosthesis-adapted training methodology produces superior performance outcomes in T46 para-athletes compared to a standard training curriculum. The statistically significant post-intervention between-group differences across all six performance indicators, emerging from a baseline of confirmed group equivalence, represent a robust methodological demonstration of the developed methodology's effectiveness.

The superiority of the experimental group on sprint performance indicators is consistent with the broader sports science literature demonstrating the benefits of specificity-matched training prescription in sprint events [12]. The three-block exercise complex specifically addressed the acceleration deficit that characterises T46 performance: Block I exercises targeted the start phase where T46 athletes typically lose ground relative to able-bodied competitors, Block II exercises developed the race-specific endurance necessary to sustain maximal velocity through the final 30–40 m of the 100 m event, and Block III exercises ensured that prosthesis-related factors did not act as a rate-limiting constraint on technical and physiological training adaptation.

The functional monitoring data underscore a point of broad relevance to para-athletics training practice: individual variation in physiological response to training is substantial even within a biomechanically defined classification category. The 41% range in TRIMP scores (51–72) and the 13% range in estimated VO₂max (49.5–55.8 ml/kg/min) observed across just six athletes in a single training session highlight that group-average training prescriptions are likely to be suboptimal for a significant proportion of athletes. The integration of regular physiological monitoring into the training process — as operationalised in the present methodology through HR-zone-targeted exercise prescriptions — provides a practical mechanism for managing this heterogeneity in real-world coaching contexts.

The push-up endurance finding (experimental group advantage of 5.8 repetitions, $p < 0.01$) is particularly noteworthy given that Block III of the specialised complex included only limb-symmetry and prosthesis-adaptation work rather than direct upper-body strength training. This suggests that the improved residual limb conditioning and prosthesis-socket interface quality achieved through Block III may have facilitated enhanced upper-body training quality across the broader programme — a prosthesis-mediated transfer effect that has not been previously reported in the para-athletics literature to the authors' knowledge.

The annual periodisation plan's five-period structure represents a theoretically grounded adaptation of classical Block Periodisation principles [13] to the specific demands and constraints of elite para-athletics. The inclusion of a dedicated transition period with standardised prosthesis maintenance protocols addresses a gap in existing para-athletics periodisation models, which frequently neglect the equipment management dimension of athletic preparation. Prosthetic carbon-fibre blade components have defined service lives and performance-degradation characteristics that interact with training load, and systematic post-season inspection and replacement protocols are necessary to ensure that equipment factors do not confound performance development assessments at the outset of the subsequent training year.

Conclusion. This study developed, implemented, and empirically evaluated a comprehensive annual training system for highly qualified T46 para-athletes in sprint and middle-distance running disciplines. The principal conclusions are as follows:

1. Control and experimental groups demonstrated statistical equivalence at baseline on all five anthropometric measures (height, weight, leg length, arm length, residual limb length) and all six physical fitness tests (60 m, 100 m, 200 m sprint times; standing long jump; triple jump; push-up endurance), with all intergroup comparisons yielding $p > 0.05$. This equivalence

validates the experimental design and supports attribution of post-intervention differences to the differential training methodology.

2. Functional state monitoring revealed substantial individual variation among T46 athletes in TRIMP (range 51–72), HR_max (180–196 bpm), and estimated VO₂max (49.5–55.8 ml/kg/min) within a single standardised training session. These data informed individualised exercise intensity prescriptions and highlight the necessity of routine physiological monitoring in elite para-athletics coaching practice.

3. A three-block specialised exercise complex was developed comprising: Block I (start mechanics and acceleration, 0–30 m); Block II (speed-endurance and running economy, 60–200 m); and Block III (prosthesis adaptation and residual limb conditioning). The complex specifically addresses the technical, physiological, and prosthesis-related determinants of T46 performance that are insufficiently targeted by conventional sprint training programmes.

4. The annual periodisation plan — comprising five structured macro-periods (General Preparatory, Special Preparatory, Pre-Competition, Competition, and Transition) with defined volume, intensity, training content, and prosthesis maintenance protocols for each period — provided the periodisation framework within which the specialised exercise complex was delivered.

5. Post-intervention testing demonstrated statistically significant between-group performance advantages for the experimental group across all six fitness tests, with the largest effects observed for 100 m sprint ($p < 0.01$, $t = 3.36$), 200 m sprint ($p < 0.01$, $t = 3.74$), and push-up endurance ($p < 0.01$, $t = 4.15$). These findings confirm the effectiveness of the developed methodology in improving competitive para-athletics performance.

6. The prosthesis-mediated transfer effect observed in upper-body strength performance and the absence of any training-related skin-socket complications in the experimental group suggest that systematic inclusion of residual limb conditioning and prosthesis maintenance protocols within the annual training plan yields benefits beyond immediate technical performance improvement.

Future research directions include longitudinal evaluation of the methodology across multiple training years; investigation of its applicability to female T46 athletes and to other para-athletics sprint classifications (T45, T47); incorporation of three-dimensional gait analysis for biomechanical outcome assessment; and exploration of technology-assisted monitoring solutions including GPS-based velocity profiling and real-time blade force sensors for further individualisation of training prescriptions.

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