Original Article

Cross-sectional analysis of rowing power and technique of german junior women in the eight

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ABSTRACT

Mattes, K., Schaffert, N., Manzer, S., & Böhmert, W. (2015). Cross-sectional analysis of rowing power and technique of german junior women in the eight. *J. Hum. Sport Exerc., 10*(2), pp.571-582. Since ten years, the German Rowing Federation (DRV) annually conducted 2000-m-race-tests with the best-performing athletes at the beginning of the immediate-pre-competition-preparation (IPCP) for the World-Rowing-Junior-Championships (WRJC). According to previous findings, differences between year-groups, correlations between anthropometric-data, rowing-power and technique development were tested to identify trends and to define a performance-strategy. Twenty test-runs of the junior-women's-Eight (N=156) were studied using a mobile-measuring-system that records rowing-force and rowing-angle. Body height, body mass, average handle-power with its components handle-force, velocity and handle-displacement per stroke and further rowing-technical characteristics of the rowing-stroke-length were considered and WRJC-race-times used as external-criteria. Single-factor-variance-analysis, linear-correlation, regression-analysis and cluster-analysis were calculated. Significant differences were found between year-groups in body height, body mass and in characteristic values for rowing-power and technique and significant correlations between body height and body mass with rowing-power. Further, six performance-groups were identified by rowing-technique-data. Significant reduction was found in crew's WRJC-race-time, reflected in handle-power and its determinants. Cross-sectional-comparison showed significant increase in average handle-power and handle-force per rowing-stroke at higher stroke frequency. Based on the cross-sectional-data, selection and year-group influences, together with exercise-induced-effects, should be considered as causes. Results show a functioning preparation-system within the DRV for better prepared-junior-athletes to commence the IPCP.
Key words: PERFORMANCE ANALYSIS, RACE ROWING, CROSS-SECTIONAL ANALYSIS, JUNIOR WOMEN.

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INTRODUCTION

Annually, for the past ten years, the German Rowing Association (DRV) conducted 2000-m race tests with the best performing athletes. These tests took place at the beginning of the immediate pre-competition preparation (IPCP) for the World Rowing Junior Championships (WRJC) in June/July. Using a mobile measuring system (Boehmert & Mattes, 2003), the individual rowing performance and technique as well as the conversion of the developed performance attributes into mechanical power and boat velocity were examined under the specific conditions existing in large boats (eight 8+) over a 2000-m race distance. An eight is a rowing boat that is designed for eight rowers, who propel the boat with sweep oars, and is steered by a coxswain. The aim of the cross-sectional study was to compare the rowing performance and technique of German rowers, and, in conjunction with findings from the literature, to describe its development over ten years with the ultimate aim of identifying trends in candidate performance and to specify performance strategies necessary for international success in the eight. By analysis of oar-handle force and velocity, as well as of the technical characteristics of the stroke-arc, rowing performance and its development and selective performance groups of athletes are identifiable. These groups are intended to identify the aggregate boat-class specific performance requirements and to facilitate its evaluation in practice by the coaches. The external criteria of the 2000m race time and placing of the German eight at the WRJC provide a practical evaluation in training of the test results.

LITERATURE FINDINGS

Development of the 2000-m-reace time at the WRJC

When using race times of world championships or other international regattas it is important to note that these are only of limited significance due to the different conditions. For example, times may vary as a result of altered environmental conditions (regatta course, weather and water conditions) for women and men up to 40s from year to year (Cornett, Bush & Cummings, 2008). It was found that 91.5% of the annual race time variations are caused by weather and only 8.5% by the factor of athlete/crew (Kleshnev, 2011). Different authors calculated the race time analysis of finals at the Olympics and/or WRJC (Schwanitz, 2005; Kleshnev, 2011). Since there are differences in the analysis methods used, the results differ from each other. However, there is a consensus that even in the juniors a reduction in race times at WRJC takes place but the concrete data on the annual decrease are contentiously discussed. Figure 1 shows such a trend analysis of the average boat speed in the period from 1993 to 2009.

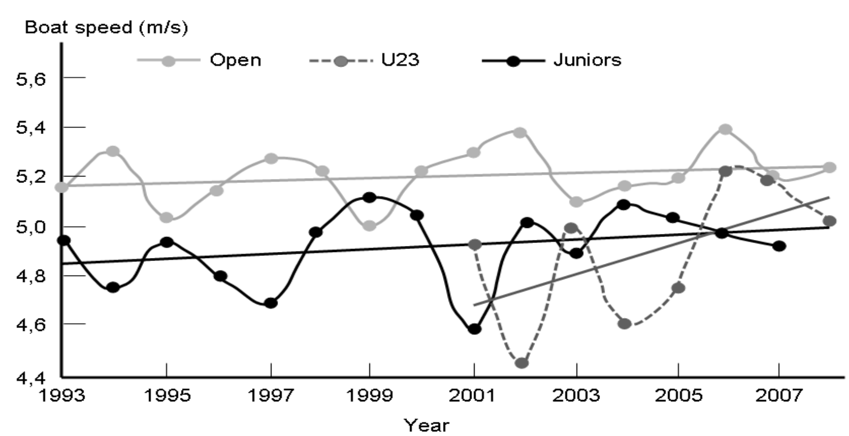

Figure 1. Average boat speed and the trend in eleven comparable boat classes (modified from Kleshnev & Nolte, 2011)

Based on this analysis, a velocity increase of 0.203% per year is given and for the winner in the eight at the WRJC in 2012 an end time of 6:10,2 min is expected (Kleshnev & Nolte, 2011).

Anthropometric performance requirements

To identify specific anthropometric profiles of the rowers, Bourgois et al. (1998) investigated 220 participants in the 1997 Junior World Championships. The body heights and body masses of the junior women are within the average range of values that are defined for adult female rowers in the open class. There were marked differences in anthropometric data between the finalists and non-finalists of the WRJC.

Table 1. Comparison of anthropometric data of international female rowers (Bourgois et al., 2001)

	Open class (n=51)	Juniors (n=220)	Finalists (n=112)	Non-finalists (n=94)
Age [years]	23.8		17.5	
Body height [cm]	174.3	174.5	176.6	172.7
Body mass [kg]	67.4	69.5	71.3	67.7

Oar-handle power and its components in the racing boat

To determine rowing power in the racing boat, traditionally, the stroke rate, the oar angle and the oar-handle or swivel forces are measured. The rowing force is recorded directly as a force applied on the handle (Gerber, 1991; Smith, Galloway & Patton, 1994; Baudouin & Hawkins, 2002; MacBride, 2005; Kleshnev, 2011; Mattes, 2011) or indirectly as a reaction force at the pin (Nolte, 1979; Dal Monte & Komor, 1980; Smith & Loschner, 2000; Draper, 2006). Handle force is typically measured using a strain gauge mounted perpendicularly on the oar-handle as the bending moment of the oar. If the blade is in the water and the rower pulls on the oar, then the oar bends in proportion to the applied force. In order to determine the handle force, the oar is calibrated in advance on-land by a known force applied at a defined point on the oar's inboard-handle. For senior women (open class) in sweep oar rowing Zaciorskij & Jakunin (1981) refer to mean handle forces of 245-294N. The handle power is an important descriptive value, because this affects the propulsion per stroke of the boat directly.

The handle power alone is a necessary but not a sufficient parameter for fast rowing, because the forces on the stretcher and the sliding seat are not considered. A high handle power output is developed when, at a technically-mastered stroke frequency, a high handle work output per stroke is generated. This in turn produces high draw-forces in the individual parts of the propulsive phase (start and middle of the drive and the finish) as well as a long work-path and consequently greater impulse. Ultimately, by means of a long rotation (stroke length) of the oar it is possible to achieve a long forward position (forward angle, minimum angle) and a vertical catch without air shot, a long finish position (or long maximum angle) and a long draw of the stroke, together with full utilisation of the slides (extension of the legs) can be achieved. The long work-path must be achieved in a short time (propulsive phase time) or, to put in another way, high oar-handle forces during the propulsive phase must correspond, as an indirect expression of the correct water work, with optimally high handle speeds in the start, middle and the finish of the drive, as an indirect expression of correct water work.

Biomechanical standards for the evaluation of oar-handle power and its components have been published previously (Kleshnev, 2011). However, the data included in the previous analysis were only derived from adult rowers. From these data, the values for senior women as well as actual measured data (Kleshnev, 2007) are included in table 2.

Table 2. Biomechanical standards for assessing rowing power (mod. from Kleshnev, 2011) and measured data at race stroke rate, women sweep oar rowing, open class (Kleshnev, 2007)

Biomechanical value	Biomechanical standards women sweep oar rowing (Kleshnev, 2011)		Data at race stroke rate (Kleshnev, 2007)
	Coxless pair (W2-)	Eight (W8+)	
Target time for 2000m	6:52.9	5:53.1	-
Stroke rate [1/min]	36	39	-
Drive time [s]	0.86	0.81	-
Oar angle at the catch [°][1]	34	34	36.5
Oar angle at the release [°][1]	124	124	123.4
Stroke length [°]	90	90	86.9
Handle force per drive [N]	300	300	238
Handle power per drive [W]	400	400	308

MATERIAL AND METHODS

The studies included a total of 20 test-runs in the eight measured from 2001 to 2011. The test data from 2003 (two runs) were not considered because there were no external criteria of race time and placing at the WRJC owing to illness amongst the German eighth. Owing to faulty measurements, the data from four other rowers were not evaluated. The analysis included data from a total of 156 rowers (N=156; BH = 1.79 ± 0.05m; BM =70.2 ± 5.8kg). The sample was further differentiated into participants in the eighth at the WRJC (N=77; BH = 1.79 ± 0.05m; BM =71.6 ± 6.0kg) and athletes who did not row in an eight (N=79; BH = 1.78 ± 0.05m; BM =68.9 ± 5.3kg).

The group of participants not in an eight is composed of substitute rowers for the eight, rowers who participate in other boat classes or who did not participate in the WRJC. The test runs were carried out as part of the selection of the German eighth for the WRJC. Consequently, the best-performing athletes in each year participated. Prior to the test runs, the boats and the oars were adjusted according to the individual needs of the rowers. Then a test-run, lasting approximately 30 minutes was conducted to check the adjustments and to modify as necessary after. The test itself involved an individual warm-up program, a stroke rate incremental test (four stroke rates steps from 20, 24, 28 up to 32 strokes per minute with 15 rowing strokes each) and a 2000-meter competition test on the regatta course of Berlin-Gruenau. The physical load before the competition test was equivalent to those of regular regattas. The environmental conditions during the test runs ranged from smooth to slightly choppy water and from 18 to 30°C air temperature. During the test runs, the wind varied between 0-2 on the Beaufort scale. For the analysis, only the runs in a direction with a tailwind were considered. This paper presents only the results of the 2000-meter race. The measurement of the biomechanical parameters was carried out using the German mobile measuring system 2000 (Mobiles Messsystem ["MMS"] 2000) (Boehmert & Mattes, 2003). The system recorded the oar-force as a bending moment on the handle, wherein a strain gauge measured the deflection of the oar proportional to the applied force. The resolution of the handle force was 0.25N (Lorms, 1998). The oar angle was recorded with a high-resolution magnetic field sensor that was attached to the pin. By rubber band the potentiometer was connected to the handle, thus transferring the handle movement to a magnetic field-sensitive circuit. The resolution of the oar angle was 0.1°. The measurements were made with a sampling frequency of 100Hz. The structure of the rowing stroke in drive and recovery as well as further sub-phases was characterised by the oar angle and patterns in the handle force. Figure 2 shows the three sub-phases of the drive (start, middle and finish of drive) and their definitions.

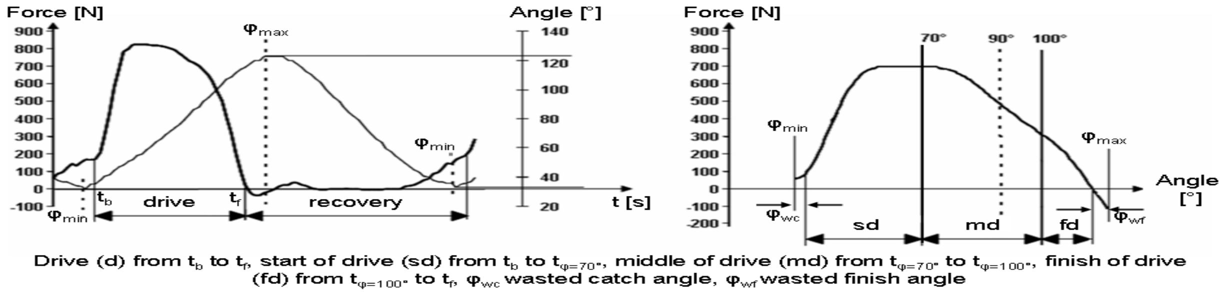

Figure 2. Definition of the drive and its sub-phases on the basis of oar angle and events of handle force

Data on the following parameters were determined: average handle power per rowing cycle over the 2000 meter distance together with its components, handle force, handle velocity and handle displacement. This included the stroke length and the catch and finish angles, the handle force in the start, middle and finish of the drive as well as any angle lost at the catch and finish (Tab. 3).

Table 3. Comparison of the characteristic values of the Mobile Measuring system from 2001 to 2011, one-way analysis of variance with the factor year, N=156

Characteristics	Value [unit]	Data of the analysis of variance		
		F^1	p	η_p^2
Body height	B_H [m]	1.79	0.00	0.11
Body mass	B_M [kg]	0.52	0.86	0.03
Stroke rate	S_r [1/min]	5.94	0.00	0.28
Handle power per cycle	P_{hc} [W]	2.08	0.04	0.12
Handle power per drive	P_{hd} [W]	5.35	0.00	0.26
Handle work per drive	A_{hd} [J]	1.94	0.05	0.11
Handle force per drive	F_{hd} [N]	2.08	0.04	0.12
Handle velocity drive	v_{hd} [m/s]	38.47	0.00	0.72
Handle displacement per drive	s_{hd} [m]	3.41	0.00	0.18
Drive time	t_d [s]	5.17	0.00	0.26
Stroke length	S_l [°]	4.11	0.00	0.21
Minimum oar angle	φ_i [°]	2.32	0.02	0.13
Maximum oar angle	φ_x [°]	4.54	0.00	0.23
Wasted catch angle (front reversal)	φ_{wc} [°]	10.03	0.00	0.40
Wasted finish angle (back reversal)	φ_{wf} [°]	8.69	0.00	0.36
Handle force in start of drive	F_{hsd} [N]	2.69	0.01	0.15
Handle force in middle of drive	F_{hmd} [N]	4.91	0.00	0.25
Handle force in finish of drive	F_{hfd} [N]	3.24	0.00	0.18
Handle velocity in start of drive	v_{hsd} [m/s]	34.89	0.00	0.70
Handle velocity in middle of drive	v_{hmd} [m/s]	40.32	0.00	0.73
Handle velocity in finish of drive	v_{hfd} [m/s]	19.22	0.00	0.56

The evaluation of the total sample (N = 156) was carried out by a one-way analysis of variance with the factor year to determine differences between the years. Estimation of the effect size was realised by using the partial eta-squared (ηp2) according to the classification by Cohen: ηp2 values of ≤0.10 corresponding to a small effect, ηp2 >0.20 to a medium effect and ηp2 >0.38 to a large effect (Cohen, 1988). The analysis included a correlation between the anthropometric data and characteristics of the rowing performance. Also a cluster analysis of the handle power was conducted in order to form groups of different rowing performance (Phc). Finally, a linear regression analysis depending on the year of measurement was calculated for the sub-sample of the participants in the eight of the WRJC (N = 77). The normal distribution and homogeneity of variances, as prerequisites for the statistical tests, were controlled using the Kolmogorov-Smirnov test and the Levene test. The statistical analysis was performed using SPSS version 15.0, SPSS Inc., Chicago, IL, USA.

RESULTS

Development of the race time within the period of investigation

A time improvement of average -1.4 s/year by the winners in the WJ eight took place in the analysis period from 2001-2011, whereas the low performance level in 2002 and the short race times in 2001 were considered (fig. 3). On average, the differences in race time between the winners and the German eight became smaller. The trend lines in figure 3 are approximately but not exactly parallel. The average race time reduction of the German eight was -1.6 s per year. The placing of the German juniors was usually in the medal zone (except in 2004), but the German eight won the event “only” in 2005 and 2011. Because of the reduced race times of the German eight, improvements in individual rowing performance and technique are to be expected.

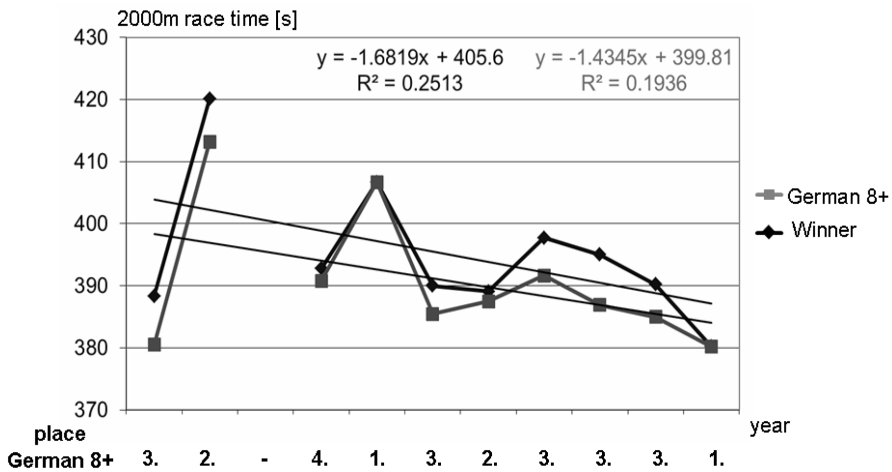

Figure 3. Race time development of the winner and the German eight in the WRJC from 2001-2011

Differences in rowing performance over the years

First, the results for all participants in the tests are compared over the years. The results of the analysis of variance showed that body mass did not differ significantly within the period of investigation. In contrast, there was a significant difference in body height as well as in several characteristics of rowing performance and technique (Tab. 3).

Significant differences between the years for the following characteristic value were found:

- stroke rate (Sr), average handle power per cycle (Phc,) and per drive (Phd), handle force (Fhd) and handle velocity (vhd) as well as the effective stroke length (Sl),
- minimum and maximum oar angle (φi and φx) as well as the wasted catch and finish angle (φwc and φwf),

- handle forces during the start, middle and finish of the drive (Fhsd, Fhmd and Fhfd),
- handle velocity during the start, middle and finish of the drive (vhsd, vhmd and vhfd).

Correlative relationships between anthropometric and characteristics of rowing performance

The correlation analysis of anthropometric and biomechanical data gave the following results (Tab. 4). Body height was positively correlated with body weight, the handle power per cycle (Phc) and the stroke length (Sl). The body mass was positively correlated with body height and with the handle force (Fhd) and handle power values (Phc and Phd). The largest correlation coefficients were found for the relationship between body height and mass.

Table 4. Relationships between anthropometric data and characteristics of rowing performance, linear correlation coefficient, female junior, N=156

	B_M	S_r	P_{hc}	P_{hd}	F_{hd}	v_{hd}	s_{hd}	t_d	S_l	$φ_i$	$φ_x$
B_H	0.60**	-0.25**	0.19*	0.15	0.11	0.11	0.22**	0.12	0.25**	-0.03	-0.15
B_M	1	-0.22**	0.23**	0.23**	0.22**	0.05	0.12	0.05	0.15	-0.02	0.31

** highly significant r>0.21; * significant r >0.16

Group forming for the evaluation of the individual rowing performance

Based on the average handle power per cycle (Phc) six performance groups were formed for all examined athletes and highlighted for a more detailed characterization with further rowing technical data (tab. 5). Performance group (PG) 1 included the most powerful rowers and PG 2, the weakest rowers in the eight. PG 1 considered the tallest (BH = 1.81 ± 0.05 m) and heaviest (BM = 72.7 ± 6.0 kg) female athletes. In addition, these athletes achieved the highest handle force in the drive (283 ± 14N) as well as the largest stroke length (87.3 ± 2.1°) with a long effective working path of the handle way because of low wasted catch and finish angle in the front and back reversal (φwc = 2.8 ± 1.2° and φwf = 5.0 ± 2.1°) at a comparable stroke rate (33.6 ± 0.4 strokes per minute) and handle velocity (1.93 ± 0.06m/s). Moreover, the formation of groups according to the handle power is very well reflected by the handle force.

Table 5. Mean value and standard deviation of the six performance groups according to the handle power per cycle (Phc) and the associated technical characteristic values, N = 156

Group	Number	B_H [m]	B_M [kg]	S_r [1/min]	P_{hc} [W]	A_{hd} [J]
1	22	1.81 ± 0.05	72.7 ± 6.0	33.6 ± 0.4	225 ± 7	402 ± 13
2	42	1.79 ± 0.04	70.5 ± 6.3	33.7 ± 0.5	210 ± 5	374 ± 9
3	36	1.78 ± 0.05	70.8 ± 5.8	33.6 ± 0.5	198 ± 3	353 ± 8
4	31	1.79 ± 0.04	68.8 ± 4.9	33.7 ± 0.5	188 ± 3	334 ± 7
5	19	1.77 ± 0.06	68.1 ± 5.2	33.7 ± 0.4	176 ± 5	313 ± 9
6	6	1.79 ± 0.04	69.0 ± 5.2	33.9 ± 0.5	164 ± 2	289 ± 2
Group	Number	P_{hd} [W]	F_{hd} [N]	v_{hd} [m/s]	s_{hd} [m]	t_d [s]
1	22	566 ± 35	283 ± 14	1.93 ± 0.06	1.41 ± 0.05	0.71 ± 0.04
2	42	547 ± 31	274 ± 12	1.94 ± 0.06	1.37 ± 0.06	0.69 ± 0.04
3	36	511 ± 32	262 ± 14	1.90 ± 0.09	1.35 ± 0.07	0.70 ± 0.04
4	31	492 ± 28	252 ± 12	1.91 ± 0.07	1.34 ± 0.06	0.68 ± 0.04
5	19	467 ± 21	240 ± 7	1.90 ± 0.07	1.31 ± 0.03	0.67 ± 0.03
6	6	444 ± 14	227 ± 14	1.92 ± 0.09	1.29 ± 0.07	0.65 ± 0.02

Group	Number	S_l [°]	φ_i [°]	φ_x [°]	φ_{wc} [°]	φ_{wf} [°]
1	22	87.3 ± 2.1	36.4 ± 2.3	123.6 ± 1.9	2.8 ± 1.2	5.0 ± 2.1
2	42	86.6 ± 2.3	36.6 ± 2.1	123.1 ± 1.6	3.5 ± 1.7	6.2 ± 2.1
3	36	85.5 ± 2.7	37.1 ± 2.2	122.6 ± 1.6	3.0 ± 1.6	6.8 ± 1.9
4	31	85.8 ± 2.3	36.7 ± 2.1	122.5 ± 1.9	3.4 ± 1.2	7.2 ± 2.1
5	19	84.8 ± 2.3	37.3 ± 1.7	122.1 ± 1.7	3.8 ± 1.5	7.5 ± 2.1
6	6	85.9 ± 2.3	37.6 ± 0.8	123.5 ± 2.2	3.8 ± 2.2	9.5 ± 2.4

Regression analysis of rowing performance of the participants in the WRJC in the Eighth

In addition, the subsample of participants in the WRJC in the eighth (N = 77) was examined in order to find trends over the years on the basis of a linear regression analysis (table 6). Significant changes were observed in nine values. In the period of investigation, a significant decrease in body mass (BM) and stroke length (Sl) was found, whereas the stroke rate (Sr), the handle power in the cycle (Phc) and the handle power per drive (Fhd) increased significantly. The handle velocity (vhd), the effective handle displacement per drive (shd) and the drive time (td) showed no significant changes. The reduction of the handle displacement resulted from a significant bigger minimal oar angle in the front reversal (φi) with comparable maximum oar angles in the back reversal (φx). The wasted catch angle (φwc) prolonged significantly. However, since the wasted finish angle was reduced the effective handle displacement (shd) remained unchanged although the stroke length decreased.

Table 6. Correlation coefficients of linear regression analysis (y = mx + n) of the participants in the WRJC in eighth from 2001 to 2011 (no indication on slope (m) and the constant term (n), y = parameter, x = year, r = correlation coefficient, ** = highly significant, N = 77

B_H [m]	B_M [kg]	S_r [1/min]	P_{hc} [W]	A_{hd} [J]	F_{hd} [N]	v_{hd} [m/s]
-0.211	-0.405**	0.386**	0.509**	0.382**	0.384**	-0.041
s_{hd} [m]	t_d [s]	S_l [°]	φ_i [°]	φ_x [°]	φ_{wc} [°]	φ_{wf} [°]
-0.063	0.119	-0.356**	0.345**	-0.173	0.705**	-0.711**

Figure 4 illustrates the course of the average handle power per cycle (Phc) and its main components, depending on the year of the study. The victory at the WRJC in 2005 and 2011 were determined by high average handle power. The highest recorded handle power (219 ± 8W) as well as the highest average handle force (286 ± 12N) of German finalists in the eight were measured in 2012. By comparing the data of the winner in 2005 and 2011, it became clear that there were differences in the performance components. Thus, in 2005 a longer stroke length (Sl) with lower handle force (Fhd) was registered in comparison to 2011.

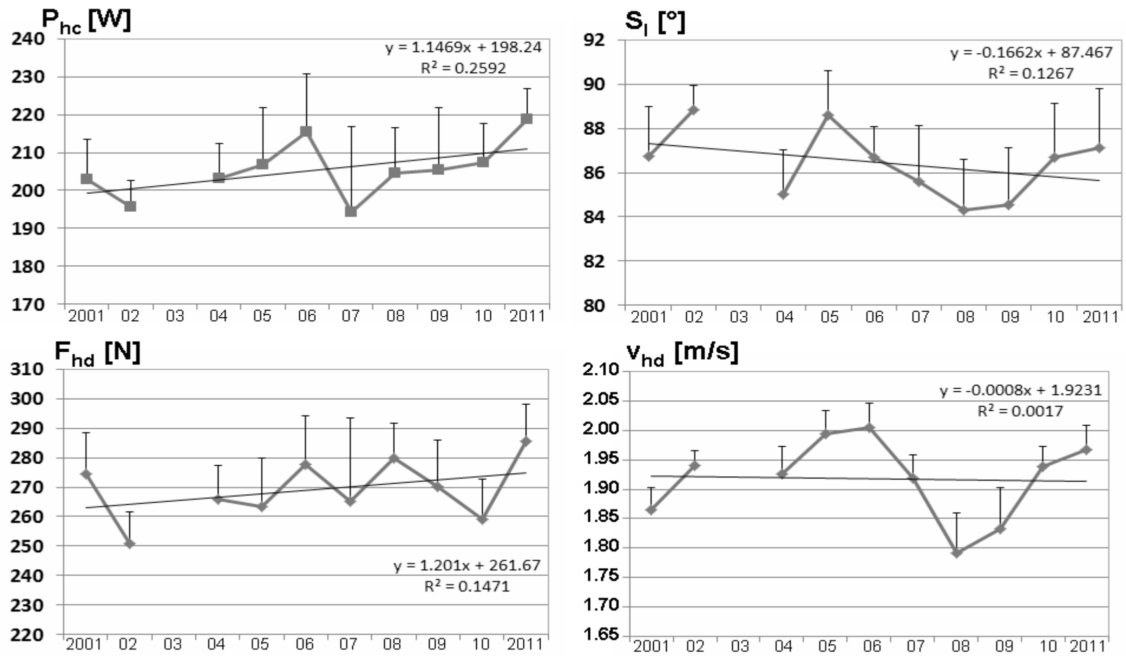

Figure 4. Change of handle power per cycle (Phc), the stroke length (Sl), the handle force (Fhd) and velocity (vhd) in the drive of the participants in the eight of WRJC, 2001-2011, N = 77

DISCUSSION

The key tasks in the IPCP consist in the improvement of individual rowing technique and the harmony of the team in the big boat combined with a further increase in strength and endurance. The variance analysis revealed a number of significant differences between the years, i.e., at the beginning of each year, the athletes had a different performance level. This affects the anthropometric data, the handle power and its components handle force, velocity and stroke length. The training during the IPCP must be designed taking into account the respective strengths and weaknesses of the rowing crew formed each year. The respective training objectives are derived explicitly through the performance diagnostics at the beginning of the IPCP.

The anthropometric requirements of the German Junior Women (N = 156) were above findings for the finalists of the 1997 WRJC refereed by Bourgois et al. (2001), (Table 1). Body height and mass of the junior women was already at the same level of senior women open class (Table 1). Therefore, it is assumable, that, in comparison with the average of the WRJC-finalists, the German juniors had no disadvantages with regard to the anthropometric requirements. The influence of body height on rowing performance was proven beyond reasonable doubt in the German Junior homogeneous sample. The larger female athletes reached, on average, higher handle power benefits due to longer stroke lengths. In addition, tall female athletes were significantly heavier.

On the other hand, the higher body mass correlated with a significant higher mean handle force, which must be considered as an indication of a higher absolute performance. Even in the PG 1 the taller and heavier rowers were classified. In this respect, the findings confirm the differences between finalists and non-finalists in terms of anthropometric data of Bourgeois et al. (2001).

The grouping was accentuated by the handle power per cycle (Phc), because this complex value takes several parameters into account such as the handle force, velocity and displacement in the drive as well as the stroke rate and the total cycle time. In comparison to the biomechanical standards for women in the open classes of Kleshnev (2011), the PG 1 showed striking differences in the stroke rate (33.6 ± 0.4 strokes per minute versus 39 strokes per minute), the handle power per drive (225 ± 7W versus 400W), the average handle force (283 ± 14N versus 300N) and the stroke length (87.3 ± 2.1° versus 90°). However it should be noted that the data of the juniors were measured at the beginning of the IPCP and not at the peak of competition. During the IPC a further increase of the characteristic values of rowing performance and technique is expected, so that the difference data of the senior women from Kleshnev (2011) should decrease.

The reported data for women (open class) over race stroke rate (Table 2) were closer to the values of PG 1 and 2. With it the most powerful German juniors achieved similar stroke length (86.9°), higher handle force (238N) but much lower handle power (308W). These differences are due to the higher stroke rate and boat velocity of the seniors, because at the same handle force the handle velocity increases as a function of the stroke rate and boat velocity. Therefore, striking differences consist in the higher body movement and handle velocity as well as in the higher handle force of the female senior. In these changing demands in top level rowing the juniors should be strongly oriented in the training.

The PG 1 includes the 22 most powerful rowers of the years 2001 to 2011 and may be characterized as a top international level for juniors in the eight. In this PG not only the tallest and heaviest rowers with high handle power and force values are summarized but also the rowers with characteristic technical features for fast rowing in big boats, such as rapid front and back reversal with low wasted catch and finish angle. On the other hand, the performance level of PG 6 isn’t sufficient for internationally successful rowing. The extracted groups represent important differences in the rowing performance and technique for big boats at the beginning of the IPCP. The PG’s clarify the requirements for international successful junior rowing.

The results of the trend analysis for the participants in the WRJC in the eight were limited by the small number of measurements (nine measurement time points). Discussion of any annual increases was avoided for this reason, although the significant correlation coefficients did give an insight into the underlying trend. The calculated race time analysis of the winner and the German eight for the WRJC confirmed the general trend of reduction in race time for this boat class. The race time reduction took place with the German athletes showed more progression in comparison with the winners at the WRJC, even taking into account the low level output in 2001. The positive trend in the race time reduction is also reflected in the development of the average handle power and its components. In cross-sectional comparison, there was a significant increase in the average handle power and force per stroke at a higher stroke rate and with a comparable effective stroke length. This was achieved, despite body showing a significant reduction and the body height showing a declining but not significant trend. Despite reduced stroke length, a similar effective handle displacement per drive was achieved by a significant reduction of the wasted finish angle. For the performance improvement several reasons are assumed which are based exclusively on cross-sectional data. Besides training-induced effects, the selection of athletes and the effects variations between different year groups on the rowing performance are possible. Nevertheless, it can be concluded that the athletes were better prepared for the IPCP with an individual higher performance level. The preparation of the athletes on the IPCP takes place primarily in the rowing clubs and regional rowing associations.

CONCLUSIONS

A functioning system of individual preparation of rowers and boat crews for the WRJC has been established in German junior rowing. Because there is continual variation amongst athletes, every year the preparation of the rowers for the WRJC is a different situation. Each year, the training content must be adapted to the performance requirements of the athletes to fulfill the key tasks of the IPCP. The test runs at the beginning of the IPCP can assist in this process because they provide a realistic picture of the conditional and technical requirements and help generate leads for the training. During the study period, an improving trend in terms of race time reduction was shown, which was conditional upon an increased rowing performance and an improved rowing technique. Moreover, the juniors were continually better prepared for higher performance in the IPCP by the rowing clubs and regional rowing associations.

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