Ger J Exerc Sport Res
https://doi.org/10.1007/s12662-022-00846-7
Received: 2 June 2022
Accepted: 1 July 2022

Eric Eils[1] · **Svenja Wirtz**[1] · **Yannick Brodatzki**[1] · **Karen Zentgraf**[3] · **Dirk Büsch**[2] · **Sebastian Szwajca**[1]
[1] Institute of Sport and Exercise Sciences, University of Muenster, Muenster, Germany
[2] Institute of Sport Science, University of Oldenburg, Oldenburg, Germany
[3] Institute of Sports Sciences, Goethe University Frankfurt, Frankfurt, Germany

Optimizing the transition from the indoor to the beach season improves motor performance in elite beach handball players

Supplementary Information

The online version of this article (https://doi.org/10.1007/s12662-022-00846-7) contains supplementary material, which is available to authorized users.

Beach handball, a relatively new sport developed in the 1990s, is based on team indoor handball, and the sport's European and World championships are consistently gaining attention. Beach handball is even being considered as an Olympic event (Gruić, Bazzeo, & Ohnjec, 2011; Handball-World.com, 2019; Iannaccone et al., 2022). The game can clearly be distinguished from its indoor version by the playing surface (sand), pitch size (27 m × 12 m), number of players on the field (4 × 4) and game duration (2 × 10 min). Another difference is in the throwing technique and the counting system, as certain throws account for two points. The spin shot (a double-leg jump with 360° rotation along the longitudinal axis) is predominantly used to score, and teams can score double with in-flights (Kempa) and specialist goals (goal keeper).

The body of literature in beach handball is constantly growing and evolving indicating further professionalization (Bon & Pori, 2020). The focus ranges, for example, from notational analysis (Iannaccone et al., 2022; Navarro, Morillo, Reigal, & Hernandez-Mendo, 2018), player profiling (Lemos et al., 2020), skill and position specific analyses (Lemos et al., 2021; Navarro et al., 2018; Zapardiel & Asín-Izquierdo, 2020), load measures (Iannaccone et al., 2022; Muller, Willberg, Reichert, & Zentgraf, 2022), physiological and kinematic requirements of beach handball (Pueo, Jimenez-Olmedo, Penichet-Tomas, Ortega Becerra, & Agullo, 2017), and energy cost considerations on sand surfaces (Balasas et al., 2013). In addition, a recent meta-analysis indicated that training sessions on sand can improve sprinting and jumping performance on firm ground as much as training on firm ground (Pereira et al., 2021).

In Germany, elite beach handball is currently almost exclusively played by indoor team handball athletes. One consequence for athletes who play both indoor and beach handball is that the indoor and beach seasons will overlap: In spring, as athletes will need to start preparing for beach handball, they will still be in the competition phase of the indoor team handball season. Also, late summer beach handball tournaments might overlap with athletes' preparation for the upcoming indoor season. Thus, the transition phases, when athletes are switching between different surfaces, are crucial concerning performance levels and injury prevention. From this perspective, a transition needs to be started early, i.e., before the end of the respective season, so that athletes can smoothly adapt to the demands of new surfaces.

Yet, coaches and athletes may be reluctant to add training on sand surfaces for fear that it will negatively affect performance on rigid surfaces and is time consuming, even though performance-enhancing training on sand surfaces can improve results on both surfaces (Ahmadi et al.; Hammami et al., 2020; Pereira et al., 2021). From that viewpoint, an optimal training intervention is one that can increase jump, sprint, and agility performance on rigid and sand surfaces and whereby the proportion of sand exercises in training sessions should increase over time. In recent articles, systematic reviews and meta-analyses, plyometric training[1], further referred to as reactive strength training, has been recommended for improving jump, sprint and agility performance in team sports (Asadi, Arazi, Young, & Saez de Villarreal, 2016; Granacher, Goebel, Behm, & Büsch, 2018; Markovic, 2007; Ramirez-Campillo et al., 2020; Saez de Villarreal, Requena, & Cronin, 2012; Slimani, Chamari, Miarka, Del Vecchio, & Cheour, 2016). In addition, the efficacy of such training bouts seems to be valid for rigid as well as soft (especially sand) surfaces (Ahmadi et al., 2021; Arazi, Mohammadi, & Asadi, 2014;

---

[1] Since *plyometric* per definition only describes the stretch phase of the muscle action, the term *reactive strength* is more suitable to describe muscle actions taking place in the stretch-shortening cycle (SSC).

Büsch, Pabst, Mühlbauer, Ehrhardt, & Granacher, 2015; Hammami et al., 2020; Impellizzeri et al., 2008). Consequently, reactive strength training bouts might be recommended as the basis for a transition training, which is the focus of the present investigation.

Therefore, the aim of the present study was to evaluate a transition phase from the indoor to the beach season to improve motor performance on sand surfaces in elite beach handball athletes. The intervention program consisted of specific reactive strength exercises, and the amount of sand-specific exercises gradually increased on a weekly basis. Standardized measurements for vertical jumps on a sand surface were conducted by transferring the complex sand surface into a controlled laboratory situation. Our hypothesis was that the intervention program would significantly increase motor performance (jump, sprint, agility) on the sand surface in the intervention group (elite beach handball players) in contrast to a control group (elite handball players who did not participate in the intervention program) without losing performance on the rigid surface.

Table 1 Anthropometric data of the intervention and control groups

Group	Intervention group (*n* = 15)		Control group (*n* = 14)		*P*-level
	Mean ± SD	Range	Mean ± SD	Range	
Age (years)	19.9 ± 3.5	18–31	21.6 ± 3.8	18–30	n. s.
Weight (kg)	75.1 ± 10.6	65–99	71.0 ± 11.6	57–98	n. s.
Height (cm)	181.5 ± 10.0	165–199	176.4 ± 10.6	166–195	n. s.
Gender (m/f)	7/8	–	4/10	–	–
Performance level indoor handball	2nd and 3rd league indoor handball		2nd and 3rd league indoor handball		–

Differences between groups (intervention, control) were tested using the independent Student's t-test
m male, *f* female, *SD* standard deviation, *n.s.* not significant

Table 2 Transition training program from indoor to sand surface

Exercise	Description	Comments
Double-leg forward–backward jumps	Athletes perform double-leg forward and backward jumps about a line in a pendulum like manner. Maximum speed with keeping ground contact to a minimum is required	A foam-bar instead a line is used after 3 weeks of exercises
Double-leg sideward jumps	Athletes perform double-leg forward and backward jumps about a line in a pendulum like manner. Maximum speed with keeping ground contact to a minimum is required	A foam-bar instead a line is used after 3 weeks of exercises
Vertical double-leg jumps with 180° rotation about longitudinal axis	Athletes perform vertical double-leg jumps while rotating 180° about their longitudinal axis and thrusting the arms upward and extending the body for as much height as possible. Ground contact time should be minimized	–
Alternate-leg diagonal bound	Emphasizing distance and diagonal trajectory, allow the lead leg to do a countermovement jump inward, shifting the weight to the outside leg for a direct push-off and extension while the knee of the leg is driven upwards. The lead foot will land first and the weight is balanced on the leg. Repetition with the other leg in opposite diagonal direction	–
Depth-jump with 180° rotation about longitudinal axis	Drop from an elevated level (box of maximum 40 cm) to the ground, minimize the ground contact time and jump as high as possible while rotating 180° about the longitudinal axis and thrusting the arms upward and extending the body for as much height as possible	Height of the box should be reduced if athletes are not able to avoid heel contact at first ground contact or when athletes show pronounced knock or bandy knees
Block-jump with 180° rotation about longitudinal axis following previous sidestep movement	Athletes perform quick sideways steps followed by a block jump at a marked position (three in total). At each mark, a block jump as high as possible while rotating 180° about the longitudinal axis is performed	–

Please note:
Transition training program should only be performed after a full warm-up and prior to the normal indoor training
Transition training program should only be performed with full concentration and highest skill quality
Transition training program should be performed twice a week (with a 48-h break between sessions) directly before the normal training routines
The complete training bout last 20 min after a short warm-up period, and each exercise is performed for 45 s followed by a 30-s break before athletes continue with the next exercise
Exercises should be performed in the above presented order
The sand proportion of the exercises should progressively increase from week to week, i.e., only exercise one is performed on sand within the first week, and all six exercises were performed on sand in the last week of the intervention program
Repetitions: week 1 (6 repetitions, 2 series), week 2 (7 repetitions, 2 series), week 3 (8 repetitions, 2 series), week 4 (6 repetitions, 3 series), week 5 (7 repetitions, 3 series), week 8 (8 repetitions, 3 series)

Methods

Participants

In all, 29 elite athletes (11 men, 18 women) participated in the study (Table 1). All players played beach or indoor handball at a high-performance level. The intervention group consisted of 15 beach handball players from the German national beach handball team (7 men, 8 women). As most of the national players also actively played indoor handball in the 2nd and 3rd German divisions, the control group was also chosen from the 2nd and 3rd German indoor handball divisions. The control group consisted of 14 players (4 men, 10 women). Subjects were free of injuries before and during the course of the study. Prior to participation, all athletes signed an informed consent form. The study was approved by the local human ethics committee of the department of Psychology and Sport Sciences of the University of Münster (ID: 2018-03-EE), and all procedures were performed in accordance with the principles of the Declaration of Helsinki.

Training intervention

The intervention was adapted from a program presented by Bansa et al. (Bansa, Novakovic, Pfänder, Zentgraf, & Büsch, 2018). It was performed twice a week (with a 48-h break between sessions) and consisted of six different exercises that were performed directly before the normal training routines. The complete training bout lasted 20 min after a short warm-up period, and each exercise was performed for 45 s followed by a 30-s break before subjects continued with the next exercise. The sand proportion of the exercises progressively increased from week to week, i.e., one of the six exercises was performed on sand within the first week, and all six exercises were performed on sand in the last week of the intervention program. **Table 2** describes the reactive strength-like exercises in more detail. Proper implementation of the training was controlled by the coaches. The aim of the intervention was to increase athletes' performance on sand surfaces without impairing their indoor performance on rigid surfaces. The intervention began four weeks before the end of the indoor season and ended two weeks after the start of the beach season.

Measurements

A custom-built sandbox (size 1.25 m × 1.25 m × 0.3 m) was used to transfer the sand surface into the laboratory to analyze the athletes' countermovement jumps (CMJ) and drop jumps (DJ) from a height of 40 cm (**Fig. 1**). The sand fulfilled the specifications of the German Volleyball Federation, section beach for indoor sand (grain size: 0.1–1.0 mm; grain shape: from round edges to rounded; grain distribution: even; $CaCO_3 \leq 2$–3%; $SiO_2 \geq 95$–98%; Borrmann et al., 2009).

To measure jumping height, a reflective ball marker was placed on the athletes' lower back at the height of the navel. Coordinates of the marker were detected using a three-dimensional motion capture system (Qualisys, Gothenburg, Sweden). For each athlete, at least three successful trials were measured and analyzed for each of the four conditions (CMJ and DJ on both rigid and sand surfaces).

Sprinting performance (5–10–20 m) as well as a handball-specific agility test (HAST; Vieira, Veiga, Carita, & Petroski, 2013) were conducted on both rigid and sand surfaces. Sprinting performance was measured using magnetic timing gates (Smartrack Diagnostics, Humotion GmbH, Münster, Germany). HAST time was measured by means of a light-gate system (wk Elektronische Zeitmessanlagen, Ditzingen, Germany). In addition, to measure reactive long jump performance on sand, athletes performed drop long jumps (DLJ), which were measured using a tape measure.

For each athlete, three successful trials were measured in each test, and the best trial was used for further analysis.

Test procedure

Before testing, athletes underwent a standardized and instructed warm-up and dynamic stretching session for 20 min. Teams were then divided into smaller subgroups. One subgroup performed the sprint, agility, and DLJ tests, while the other subgroup performed the jumping tests in the lab. The reflective marker was attached to the subjects' lower backs, and they started the jumping analysis. Due to organizational reasons, the order of the jumps and the surfaces were pseudo-randomized, where athletes started with one surface and performed both jumps, and then moved on to the next surface. Each subject had two trials to familiarize them with the jumping type and the surface. Instructions for both jumps were standardized and repeated for each bout of jumps. Wrong executions were corrected immediately. Resting time between trials and tests were provided to avoid effects of fatigue.

For sprinting assessment, the start was 1 m behind the first magnetic gate. Subjects initiated the sprint in a self-directed way. The time began recording when the athlete passed the magnetic gates, and sprinting split times were taken for 5 m, 10 m, and the total 20 m distance. For the

Ger J Exerc Sport Res
https://doi.org/10.1007/s12662-022-00846-7

E. Eils · S. Wirtz · Y. Brodatzki · K. Zentgraf · D. Büsch · S. Szwajca

Optimizing the transition from the indoor to the beach season improves motor performance in elite beach handball players

Abstract

Beach handball athletes experience an overlap during their preparation phase for the beach and the indoor season for several weeks. This transition phase from playing on an indoor surface to a sand surface is crucial for players' performance levels both on the sand and indoor surfaces, but coaches and athletes alike are concerned about possible performance impairments when training on a sand surface while still playing indoors. Therefore, we aimed to evaluate the effects of a specific transition phase from the indoor to the beach season in elite beach handball athletes. With 29 elite athletes participating in the study, we evaluated their jumping (countermovement and drop jump) and sprinting (5–10–20 m) performances and conducted a handball-specific agility test on both rigid and sand surfaces. In addition, we evaluated a drop long jump on a sand surface. Vertical jumping performance was analyzed using a 3D marker-based system on both rigid and sand surfaces under standardized laboratory conditions. All tests took place directly before and after a 6-week intervention program. The results showed that athletes in the intervention group significantly improved their performance in jumping (countermovement and drop long jump) compared to the control group. Furthermore, performance on a rigid surface was not only maintained for all tests but also significantly increased for the countermovement jump. Therefore, the intervention program is effective at improving performance during the transition from indoor to beach seasons without impairing indoor performance.

Keywords

Physical performance · Experts · Intervention · Diagnostics · Playing surfaces

Fig. 1 ▲ Laboratory situation when measuring drop and countermovement jumps on sand and rigid surfaces. The figure shows a subject prior to performing a drop jump into the sandbox. For countermovement jumps, the drop-box was removed and athletes performed directly within the sandbox from sand level. The jumps on the rigid surface were performed on the floor directly behind the sandbox

HAST, subjects also started 1 m behind the starting line. The drop long jump was performed by dropping down from a 20-cm-high platform to the sand and immediately performing a long jump. Resting times between trials and tests were assured, and instructions for each test were standardized.

After finishing either the jumping or sprinting assessment, agility and DLJ assessments, the groups switched tests. Each performance measurement at the start and the end of the whole intervention was conducted for each team group, i.e., female and male beach handball national team players and the two control teams (one for the male team, one for the female team).

Data analysis

Data processing and data analysis for all jumps were performed using the Qualisys Track Manager and MATLAB (The MathWorks Inc., Natick, MA, USA). Jumping height was detected using the trajectory of the back marker (difference between maximum and standing height). Sprint and HAST times were directly exported to an Excel® spreadsheet (Microsoft Corporation, Redmond, WA, USA).

An a priori required sample size calculation was performed using G*Power (Version 3.1.9.6) and resulted in a sample size of $n = 28$ (medium effect size $f = 0.25$, power = 0.8, correlations among repeated measurements = 0.6, number of groups = 2, number of measurements = 2, and $\propto = 0.05$; Faul, Erdfelder, Lang, & Buchner, 2007). Statistical analysis (Jamovi Version 1.2, the Jamovi project: https://www.jamovi.org) was performed by means of a mixed model analysis of variance (ANOVA) using within factors *time* (pre, post) and *surface* (rigid, sand), and a between-subject factor *group* (intervention, control). Holm correction was used for post hoc analysis. The alpha level was set to 5% and effect sizes were reported as generalized eta squared (η^2_G). The magnitude of effect sizes was interpreted on the following criteria: $\eta^2_G < 0.02$ (small), $\eta^2_G = 0.02–0.13$ (medium), $\eta^2_G = 0.13–0.26$ (large; Bakeman, 2005).

Results

Results for jumping (vertical & drop long jump), sprinting, and agility are presented in ◘ **Table** 3.

Jumping performance

The results of the ANOVA for the CMJ showed a significant interaction between *time* and *group* (F(1.27) = 14.16, $p < 0.001$, $\eta^2_G = 0.01$), a significant main effect *surface* (F(1.27) = 11.67, $p = 0.002$, $\eta^2_G < 0.01$), and a significant main effect *group* (F(1.27) = 4.86, $p = 0.036$, $\eta^2_G = 0.15$). Post hoc analysis of *time**surface**group* revealed that the intervention group significantly improved performance in CMJ on the rigid surface ($p = 0.002$) compared to the control group due to the training intervention. For the DJ, the ANOVA showed a non-significant interaction between *time* and *group* (F(1.27) = 3.63, $p = 0.07$, $\eta^2_G = 0.01$), a significant main effect for *surface* (F(1.27) = 9.47, $p = 0.005$, $\eta^2_G = 0.03$), and a significant main effect *group* (F(1.27) = 4.28, $p = 0.048$, $\eta^2_G = 0.11$). Results are presented on an individual basis in ◘ **Fig.** 2. These indicate that several but not all athletes in the intervention group improved between pre- and posttest.

Sprinting performance

The results of the ANOVA for the 5-m sprint showed a significant interaction between *time* and *group* (F(1.27) = 5.73, $p = 0.024$, $\eta^2_G = 0.003$), a significant interaction between *surface* and *group* (F(1.27) = 7.54, $p = 0.011$, $\eta^2_G = 0.01$), a significant main effect *surface* (F(1.27) = 558.22, $p < 0.001$, $\eta^2_G = 0.44$), and a significant main effect *group* (F(1.27) = 6.14, $p = 0.020$, $\eta^2_G = 0.17$). Analysis of the type of interaction between *surface* and *group* revealed an ordinal interaction; thus, both main effects *surface* and *group* are fully interpretable. Post hoc analysis of *time*group*surface* revealed that both groups did not improve performance due to the training intervention on each surface (rigid, sand) separately. Post hoc analysis of *surface*group* and main effects *surface* and *group* revealed that the performance on the sand surface was significantly lower ($p < 0.001$) for both groups compared to the rigid surface, but this difference in performance for the intervention group was smaller than that of the control group and more denoted on sand than on a rigid surface.

The results of the ANOVA for the 10-m sprint showed a significant interaction between *time* and *group* (F(1.27) = 11.05, $p = 0.003$, $\eta^2_G = 0.006$), a significant interaction between *surface* and *group* (F(1.27) = 11.69, $p = 0.002$, $\eta^2_G = 0.010$), a significant main effect *surface* (F(1.27) = 959.64, $p < 0.001$, $\eta^2_G = 0.46$), a significant interaction between *time* and *surface* (F(1.27) = 5.58, $p = 0.026$, $\eta^2_G = 0.003$), and a significant main effect *group* (F(1.27) = 5.82, $p = 0.023$, $\eta^2_G = 0.17$). Analysis of the type of interaction between *surface* and *group* also revealed an ordinal interaction, such that both main effects *surface* and *group* are fully interpretable. Post hoc analysis of *time*group*surface* revealed that the performance in the control group significantly decreased on a sand surface after the intervention period ($p = 0.043$), whereas the performance of the inter-

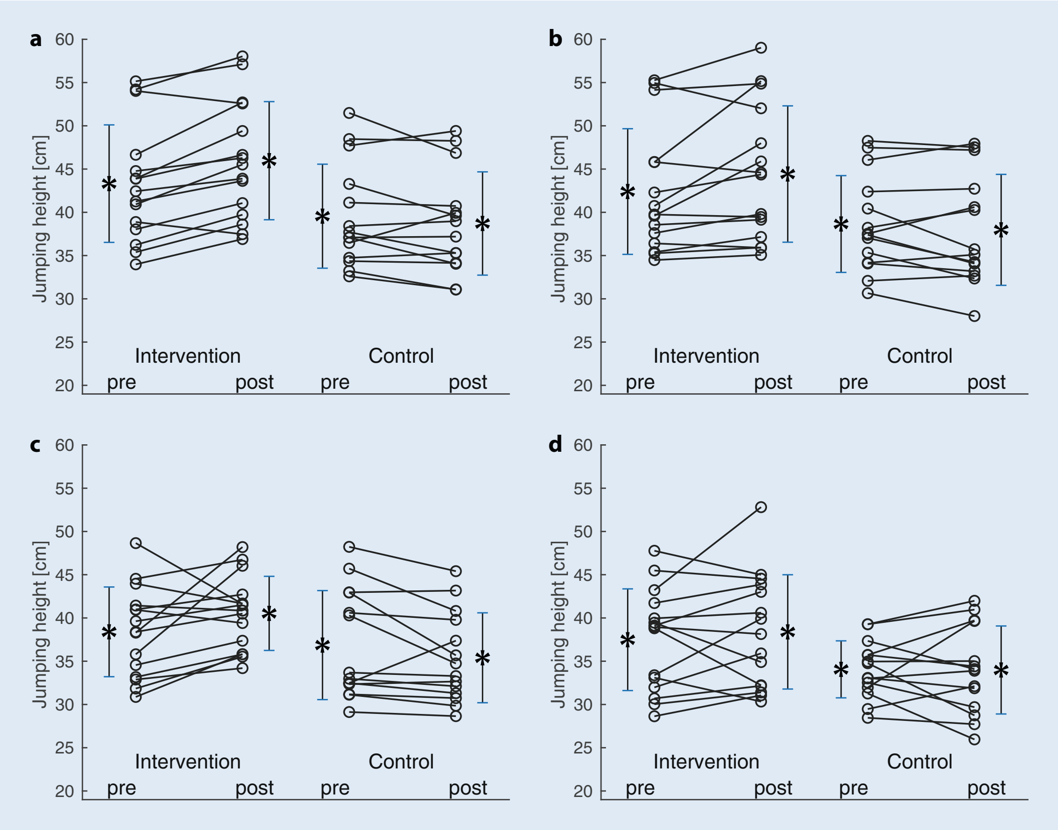

Fig. 2 ◀ Individual changes between pre- and posttests for all jumps. Please note that mean values and standard deviation are also presented as *big black asterisk* with whiskers to the left and right of the block of individual values. Subfigures represent CMJ on rigid surface (**a**), CMJ on sand surface (**b**), DJ on rigid surface (**c**), and DJ on sand surface (**d**)

vention group remained at the same level. Additional analysis of *time*surface* and the main effects *surface* and *group* revealed that performance on the sand surface was significantly lower ($p < 0.001$) for both groups compared to the rigid surface, but for the sand surface the performance of the intervention group remained at the same level, whereas that of the control group decreased between pre- and posttest.

The results of the ANOVA for the 20-m sprint showed a significant interaction between *time* and *group* ($F(1.27) = 10.50$, $p = 0.003$, $\eta^2_G < 0.01$), a significant interaction between *surface* and *group* ($F(1.27) = 10.68$, $p = 0.003$, $\eta^2_G = 0.01$), a significant main effect *surface* ($F(1.27) = 723.82$, $p < 0.001$, $\eta^2_G = 0.49$) and a significant main effect *group* ($F(1.27) = 4.94$, $p = 0.035$, $\eta^2_G = 0.15$). Analysis of the type of interaction between *surface* and *group* also revealed an ordinal interaction, so both main effects *surface* and *group* are fully interpretable. Post hoc analysis of *time*group*surface* revealed that no performance changes occurred in both groups between pre- and posttests on each surface separately, but considering the performances on both surfaces combined, the performance of the control group significantly decreased at the posttest compared to the pretest ($p = 0.007$). Post hoc analysis of *surface*group* and main effects *surface* and *group* revealed that performance on the sand surface was significantly lower ($p < 0.001$) for both groups compared to on the rigid surface, but the performance difference in the intervention group was smaller than that of the control group and more denoted on a sand than on a rigid surface.

Results on an individual basis are presented in ▣ **Fig. 3**. Most athletes in the intervention group improved their performance on rigid surface, but this tendency was less clear for the sand surface.

Agility performance

The results of the ANOVA showed no significant interaction between *time* and *group* ($F(1.27) < 0.01$, $p = 0.949$, $\eta^2_G < 0.001$), a significant main effect *time* ($F(1.27) = 22.82$, $p < 0.001$, $\eta^2_G = 0.04$), a significant interaction between *surface* and *group* ($F(1.27) = 6.58$, $p = 0.016$, $\eta^2_G = 0.010$), a significant main effect *surface* ($F(1.27) = 188.57$, $p < 0.001$, $\eta^2_G = 0.22$), and a significant main effect *group* ($F(1.27) = 4.70$, $p = 0.039$, $\eta^2_G = 0.13$). Post hoc analysis of *time*group*surface* revealed that performance in the control group significantly increased on a rigid surface after intervention period ($p = 0.003$), whereas the performance improvements in the intervention group were not significant. Post hoc analysis of main effects *surface* and *group* revealed that performance on the sand surface was significantly lower ($p < 0.001$) for both groups compared to the rigid surface, and agility performance was higher in the intervention than in the control group.

Results on an individual basis are presented in ▣ **Fig. 4a, b**. In the control group, most athletes showed improved performance in the posttest on rigid but not on sand surfaces, whereas individual performance in the intervention group was variable between pre- and posttest on both rigid and sand surfaces.

Table 3 Results and statistics for jump, sprint, and agility tests on rigid and sand surfaces

	Intervention group				Control group			
Jumping height	*Pretest*	*Posttest*	*p*		*Pretest*	*Posttest*	*p*	
CMJ on rigid surface (cm)	43.3 ± 6.8	46.0 ± 6.8	**= 0.002**	↑	39.6 ± 6.0	38.7 ± 6.0	= 1.00	
CMJ on sand surface (cm)	42.4 ± 7.3	44.4 ± 7.9	= 0.271		38.6 ± 5.6	38.0 ± 6.4	= 1.00	
DJ on rigid surface (cm)	38.4 ± 5.2	40.5 ± 4.3	= 0.778		36.9 ± 6.3	35.4 ± 5.2	= 1.00	
DJ on sand surface (cm)	37.5 ± 5.9	38.4 ± 6.6	= 1.00		34.1 ± 3.3	34.0 ± 5.1	= 1.00	
Sprint	*Pretest*	*Posttest*	*p*		*Pretest*	*Posttest*	*p*	
5 m on rigid surface (s)	0.95 ± 0.005	0.94 ± 0.045	= 0.363		0.99 ± 0.005	0.98 ± 0.050	= 0.363	
5 m on sand surface (s)	1.04 ± 0.059	1.03 ± 0.064	= 0.363		1.08 ± 0.056	1.10 ± 0.058	= 0.363	
10 m on rigid surface (s)	1.70 ± 0.097	1.68 ± 0.084	= 0.291		1.76 ± 0.084	1.76 ± 0.096	= 1.00	
10 m on sand surface (s)	1.85 ± 0.102	1.85 ± 0.127	= 1.00		1.94 ± 0.109	1.98 ± 0.112	**= 0.043**	↓
20 m on rigid surface (s)	3.03 ± 0.196	3.01 ± 0.171	= 0.363		3.13 ± 0.169	3.16 ± 0.181	= 0.149	
20 m on sand surface (s)	3.38 ± 0.222	3.36 ± 0.277	= 0.737		3.55 ± 0.247	3.63 ± 0.237	= 0.080	
Agility (HAST)	*Pretest*	*Posttest*	*p*		*Pretest*	*Posttest*	*p*	
HAST on rigid surface (s)	7.18 ± 0.57	7.08 ± 0.52	= 0.625		7.57 ± 0.53	7.32 ± 0.41	**= 0.003**	↑
HAST on sand surface (s)	7.76 ± 0.60	7.45 ± 0.71	= 0.097		8.22 ± 0.66	8.06 ± 0.44	= 0.960	
DLJ	*Pretest*	*Posttest*	*p*		*Pretest*	*Posttest*	*p*	
Drop long jump (sand) (cm)	220 ± 25	231 ± 26	**= 0.013**	↑	191 ± 22	191 ± 35	= 0.984	

Significant differences are presented in bold letters. *P*-values represent the results of the post hoc analysis using the Holm correction to evaluate the effect of the training intervention (pre–post). *Arrows* ↑ and ↓ indicate significant increase/decrease in performance between pre- and posttest measurements
CMJ countermovement jump, *DJ* drop jump, *HAST* handball-specific agility test

Drop long jump performance

Analysis of drop long jump (DLJ) performance on the sand surface showed a significant interaction between *time* and *group* ($F(1.27) = 4.62$, $p = 0.041$, $\eta^2_G = 0.01$), a significant main effect *time* ($F(1.27) = 4.75$, $p = 0.038$, $\eta^2_G = 0.010$), and a significant main effect *group* ($F(1.27) = 12.45$, $p = 0.002$, $\eta^2_G = 0.30$), whereas only the main effect *group* is fully interpretable. Results indicate that the intervention group significantly increased their performance due to the training compared to the control group and that the intervention group was at a higher performance level than the control group. Results on an individual basis are presented in ◘ **Fig. 4c** and show that all athletes in the intervention group increased their performance between pre- and posttest, whereas results in the control group were variable.

Discussion

The aim of the present investigation was to evaluate a transition phase from indoor to beach season to optimize motor performance on sand surfaces in elite beach handball athletes without declining their motor performance during the ongoing indoor season. Within this study, performance on rigid and sand surfaces was evaluated, thus enabling a direct comparison between performance levels on both surfaces. Results show that athletes in the intervention group significantly improved their performance in the CMJ on the rigid surface and the DLJ on the sand surface. The control group showed no significant improvements for jumping, sprinting, and DLJ, but they showed improved agility on a rigid surface. Therefore, the intervention program can be considered an effective tool for improving performance during the transition from the indoor to the beach season for selected skills. Furthermore, performance on the rigid surface was not only maintained but also significantly increased in CMJ. Importantly, when focusing on individual changes between pre- and posttests, only few athletes substantially decreased their performance, indicating that coaches have no need to be concerned about performance impairments on rigid surfaces when athletes again begin to train on sand surfaces.

Intervention effects

Performance improvements in our investigation were slightly smaller compared to results from other publications (Asadi et al., 2016; Markovic, 2007; Saez de Villarreal et al., 2012; Slimani et al., 2016) but do fall in the range of practically relevant changes on a rigid surface (Markovic, 2007), and for the sand surface the improvements fall in a range of 2–5%. The reason for these relatively small improvements may be because we instituted a shorter intervention period of 6 weeks rather than the recommended 8–10 weeks (Villarreal, Kellis, Kraemer, & Izquierdo, 2009) or because we applied a lower intensity or execution time (Slimani et al., 2016). Further, although the training program was supervised by coaches, individuals were partaking in the program, not whole teams, because the elite athletes trained with their standard indoor team at the beginning of the intervention phase and not with the beach teams. Thus, some athletes may not have taken full advantage of the training, diminishing the overall group effect. This may also explain why some athletes did not show improvements in the posttests (individual results in ◘ **Figs. 2, 3 and 4**).

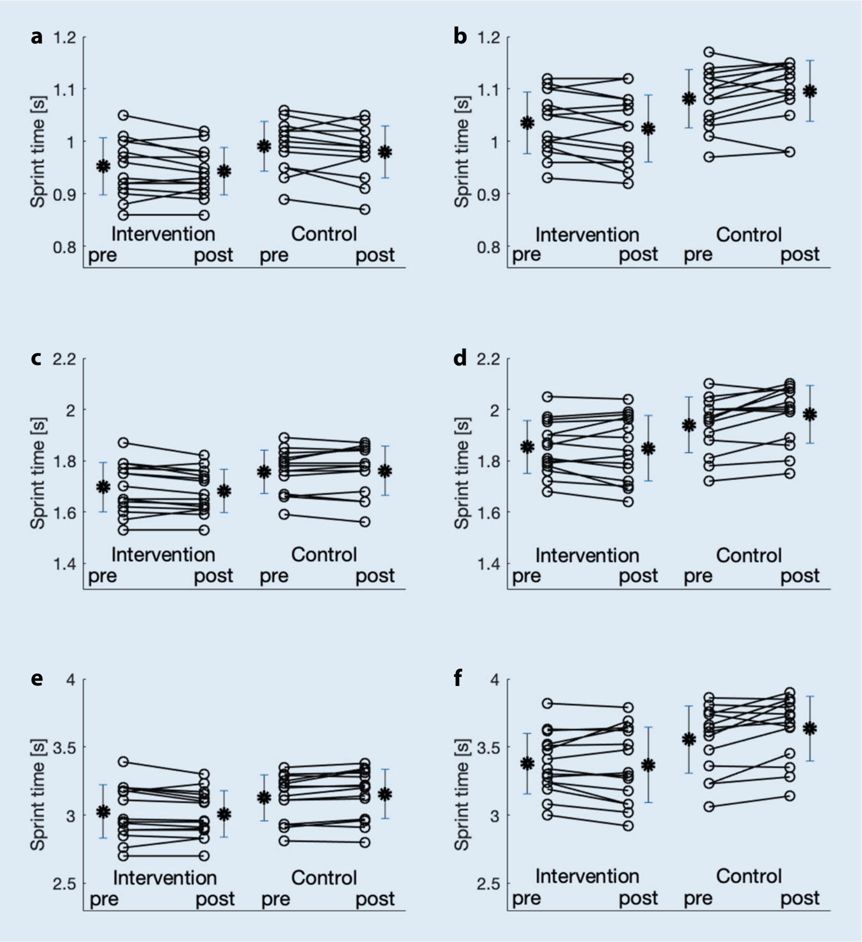

Fig. 3 ▲ Individual changes between pre- and posttests for all sprints. Please note that mean values and standard deviations are also presented as *big black asterisk* with whiskers to the left and right of the block of individual values. Subfigures represent 5 m sprint on rigid surface (**a**), 5 m sprint on sand surface (**b**), 10 m sprint on rigid surface (**c**), 10 m sprint on sand surface (**d**), 20 m sprint on rigid surface (**e**), 20 m sprint on sand surface (**f**)

However, relevant performance changes, as reflected by their effect sizes, are obvious for CMJ and DLJ, and individual results also show that most athletes responded to the intervention.

In beach handball, both CMJ and DLJ are relevant for performance because they build the basis for an effective spin shot (the most important attack jump) in beach handball (Navarro et al., 2018; Saavedra, Pic, Jimenez, Lozano, & Kristjánsdóttir, 2019). For explaining distinct effects of the training intervention concerning the different jumps (CMJ, DLJ, DJ), biomechanical considerations have to be taken into account. Previously, it has been shown that a substantial difference exists in the mechanical output and jumping performance between the slow (CMJ) and fast (DJ) stretch-shortening cycle (SSC) in jumps (Bobbert, 1990). The sand may provide a specific surface to address the slow SSC and, therefore, to predominantly influence CMJ or slow DLJ performance. However, it was also shown that reactive strength sand training influences DJ performance on a rigid surface, but the underlying processes remain unclear (Hammami et al., 2020).

In sprinting, the control group had lower performances for almost all distances and both surfaces (significantly on a sand surface at 10 m). An explanation for the significantly lower performance on the sand surface in the control group remains unclear and speculative, since constraints in the pre- and posttest were the same. However, sand conditions in the pre- and posttest, when performed outside, may differ and, thus, influence performance. Except for the jump analysis, where sand conditions were controlled between pre- and posttest in the lab, an accurate control of the sand conditions was not possible due to wind and weather. Although weather conditions were comparable between pre- and posttests, this might have influenced sprint performance in the control group but also in the intervention group (who may have performed even better). A further standardization concerning sand moisture but also sand quality (grain size and shape) is crucial to enable valid performance measurements on a sand surface in a pre-/posttest design. This will be evaluated in further investigations.

Methodological aspects

When focusing on the results of the different tests in our investigation, similar results concerning athletic performance in sprinting and agility in handball have been reported from other investigations (Asadi et al., 2016; Chaabene et al., 2019; Cherif et al., 2012; Hammami et al., 2020; Hammami, Gaamouri, Aloui, Shephard, & Chelly, 2019; Iacono, Eliakim, & Meckel, 2015; Prieske et al., 2019; Sabido, Hernandez-Davo, Botella, Navarro, & Tous-Fajardo, 2017). When focusing on jumps (CMJ and DJ), it is important to consider that results reported in the literature are related to the method used to detect jumping height (contact times, impulse-momentum method, marker-based coordinates). When using flight times to calculate jumping height, results will be lower than when derived from a marker-based approach or the impulse–momentum method (Moir, 2008) because the initial marker height is higher when plantar flexing the ankle and lifting up the body before leaving the ground. Considering this, our results for jumping are comparable to other results reported in the literature (Chaabene et al., 2019; Iacono, Martone, Milic, & Padulo, 2016; Prieske et al., 2019).

In the literature, performance diagnostics have mainly taken place on a rigid but not a sand surface, even when evaluating effects of sand-related training inter-

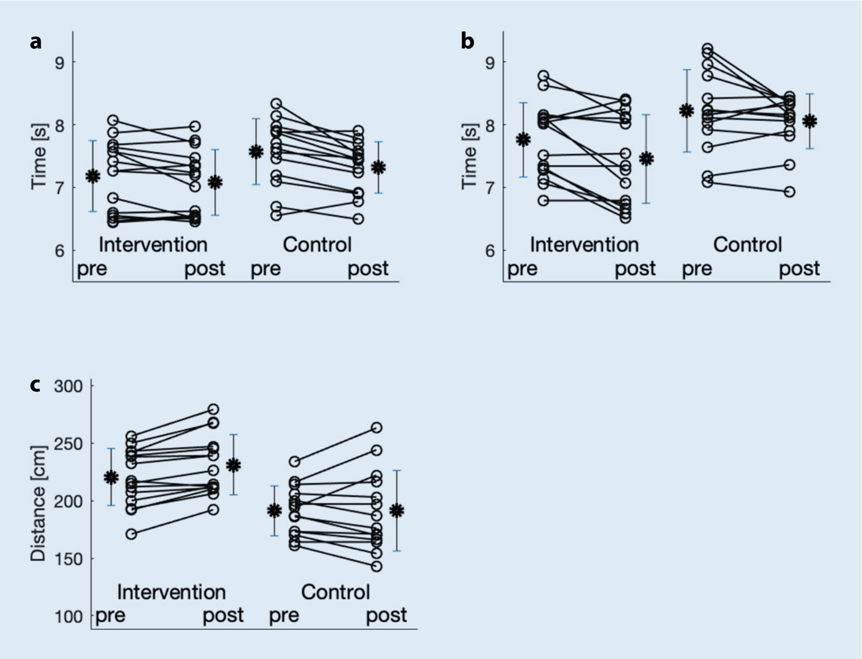

Fig. 4 ▲ Individual changes between pre- and posttests for agility and drop long jumps. Please note that mean values and standard deviations are also presented as *big black asterisk* with whiskers to the left and right of the block of individual values. Subfigures represent HAST on rigid surface (**a**), HAST on sand surface (**b**), Drop long jump on sand surface (**c**)

ventions (Hammami et al., 2020; Impellizzeri et al., 2008). In beach sports, like beach handball or volleyball, it is of special interest that performance is evaluated on sand and not on a rigid surface because this more accurately matches sport-specific performance characteristics. Performance measurements on sand surfaces are challenging and, in the present investigation, performance on both surfaces spanning different jumps as well as sprints and agility were measured. Our jump measurements in a standardized laboratory environment are particularly important for relating the performances obtained from both surfaces. Therefore, our results for all measurements on rigid and sand surface may be used as a reference for beach sport motor performances.

When evaluating the efficacy of training interventions, it is critically important that measurements during the pre- and posttest are conducted under the same or close conditions. In the present investigation, this was the case for all jump measurements under laboratory conditions. However, sometimes when evaluating performance, we had to adapt to varying external constraints (e.g., different testing locations), as the intervention occurred during athletes' competition phase (e.g., players were competing in the world championships). As such, the intervention group had to perform the posttest for sprinting and agility on a slightly different rigid and sand surface. This may have decreased the performance in the intervention group in the posttest and might explain the absence of significant performance increases in sprint and agility.

Performance evaluations in the intervention group took place in combination with training courses over several days, when athletes arrived from all over Germany. Due to organizational reasons, performance evaluations within these courses did not take place at the same times of day. Prior of each test, we investigated both the DOMS (delayed onset of muscle soreness) and TQR (total quality recovery) scale, and the intervention group showed significantly altered values for both scales in the pre- compared to the posttest. Therefore, increased muscle soreness and reduced recovery may also have influenced the results, although a general relationship between DOMS and reduced performance in athletes has not been demonstrated (Altarriba-Bartes, Pena, Vicens-Bordas, Mila-Villaroel, & Calleja-Gonzalez, 2020).

Athletes in the intervention group showed better performance on all tests compared to athletes in the control group, even though they play indoor handball in the same league. This is rather unexpected, since not all top athletes in the leagues play beach handball, and statistical analysis for the pretest condition did not show significant differences between groups. Statistical analysis (significant interaction *time***group*) underlines the better performance of the intervention group compared to the control group as a result of the intervention program for almost all tests. However, this effect was not apparent when breaking down the post hoc analysis for different surfaces. The fact that the interaction between *surface* and *group* was also significant for several parameters indicates that beach athletes perform better on a sand surface compared to the control group. In fact, beach athletes are often not only better at performing on sand but also on a rigid surface when focusing on mean and individual results. Assuming that this is either the result of the training intervention or of a long-term adaptation during athletes' beach experience, underground sand should be considered a valuable training surface that may be able to increase performance on sand but also on rigid surfaces, although the direct effect mechanism still remains unclear (Hammami et al., 2020). Influencing factors may include an increase in force, improved intra- and intermuscular coordination or changes in muscle size and architecture (Markovic & Mikulic, 2010; Prieske et al., 2019; Ramirez-Campillo, Andrade, & Izquierdo, 2013). Training on sand is often only used as an alternative to strenuous indoor training, as it is linked to reduced muscle damage (Impellizzeri et al., 2008; Miyama & Nosaka, 2004), instead of being considered a valuable surface in its own right to improve performance on rigid surfaces. We look forward to future prospective randomized controlled trials, as they may highlight the abilities and the full potential that a sand surface offers in terms of performance enhancement.

Conclusion

This is the first study to evaluate the transition from the indoor to the beach season in elite beach handball players. The results of the present study have several important implications for this transitional period. First, our findings establish a fundamental basis for performance measurements concerning jumping, sprinting, and agility performance for both rigid and sand surfaces. Second, in beach sports, performance measurements need to take place on a sand surface because the transfer from a rigid surface to beach performance still remains unclear. Third, the specific transition-intervention program will be recommended as an effective means to facilitate the transfer from an indoor to a sand surface without impairing performance on a rigid surface. This is of special interest for coaches and athletes who are concerned that training on a sand surface might impair indoor performance. Fourth, performance measurements on a sand surface are demanding, and sand characteristics are influenced by weather conditions. Moisture content and characteristics of the sand should be kept in mind when carrying out repeated measurements on sand surfaces.

Corresponding address

Prof. Dr. Eric Eils
Institute of Sport and Exercise Sciences, University of Muenster
Horstmarer Landweg 62b, 48149 Muenster, Germany
eils@uni-muenster.de

Acknowledgements. The authors would like to thank Dr. C. Brennecka for their valuable suggestions and proofreading of the manuscript.

Funding. This study was funded by a research grant of the Bundesinstitut für Sportwissenschaft (Federal Institute of Sports Science, grant No. AZ: ZMVI4-070713/18-19).

Funding. Open Access funding enabled and organized by Projekt DEAL.

Declarations

Conflict of interest. E. Eils, S. Wirtz, Y. Brodatzki, K. Zentgraf, D. Büsch and S. Szwajca have no relevant financial or nonfinancial interests to disclose. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors (except D. Büsch) certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. D. Büsch is coordinator of the scientific network of the DHB. D. Büsch certifies that he has no involvement with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

For this article, all persons gave their informed consent prior to their inclusion in the study. All human studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

References

Ahmadi, M. A.-O., Nobari, H. A.-O., Ramirez-Campillo, R. A.-O., Pérez-Gómez, J. A.-O., Ribeiro, A. A.-O., & Martínez-Rodríguez, A. A.-O. (2021). Effects of plyometric jump training in sand or rigid surface on jump-related biomechanical variables and physical fitness in female volleyball players. *International Journal of Environmental Research and Public Health*, *18*(24), 13093. https://doi.org/10.3390/ijerph182413093.

Altarriba-Bartes, A., Pena, J., Vicens-Bordas, J., Mila-Villaroel, R., & Calleja-Gonzalez, J. (2020). Post-competition recovery strategies in elite male soccer players. Effects on performance: a systematic review and meta-analysis. *PloS One*, *15*(10), e240135. https://doi.org/10.1371/journal.pone.0240135.

Arazi, H., Mohammadi, M., & Asadi, A. (2014). Muscular adaptations to depth jump plyometric training: comparison of sand vs. land surface. *Interventional medicine & applied science*, *6*(3), 125–130. https://doi.org/10.1556/imas.6.2014.3.5.

Asadi, A., Arazi, H., Young, W. B., & Saez de Villarreal, E. (2016). The effects of plyometric training on change-of-direction ability: a meta-analysis. *International journal of sports physiology and performance*, *11*(5), 563–573. https://doi.org/10.1123/ijspp.2015-0694.

Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. *Behav Res Methods*, *37*(3), 379–384. https://doi.org/10.3758/bf03192707.

Balasas, D. G., Prantsidis, D., Christoulas, K. I., Vamvakoudis, E., Papaevangelou, E., & Stefanidis, P. (2013). The effect of beach volleyball training on running economy and VO2max of indoor volleyball players. *Journal of Physical Education and Sport*, *13*, 33–38.

Bansa, K., Novakovic, A., Pfänder, J., Zentgraf, K., & Büsch, D. (2018). Reaktivkrafttrainingsprogramm für den Übergang von der Halle in den Sand (DHB-Übergangstraining). *Handballtraining*, *40*(4&5), 62–63.

Bobbert, M. F. (1990). Drop jumping as a training method for jumping ability. *Sports Med*, *9*(1), 7–22. https://doi.org/10.2165/00007256-199009010-00002.

Bon, M., & Pori, P. (2020). Various aspects of the scientific development of beach handball over three decades-from "keep it simple" to the olympic games. *Sport Mont*, *18*(2), 103–106.

Borrmann, D., Breuer, G., Kummetat, U., Morbach, A., Münster, H., Mund, J., & Palmen, M. (2009). *Planung und Bau von Beach-Sportanlagen : eine Orientierungshilfe des Bundesinstitut für Sportwissenschaft* (5th edn.). Bundesinstitut für Sportwissenschaft.

Büsch, D., Pabst, J., Mühlbauer, T., Ehrhardt, P., & Granacher, U. (2015). Effekte plyometrischen Trainings unter Verwendung instabiler Untergründe auf sportmotorische Sprung- und Schnelligkeitsleistungen von Nachwuchsleistungshandballern. *Sportorthopädie, Sporttraumatologie = Sports orthopaedics and traumatology*, *31*(4), 299–308.

Chaabene, H., Negra, Y., Moran, J., Prieske, O., Sammoud, S., Ramirez-Campillo, R., & Granacher, U. (2019). Plyometric training improves not only measures of linear speed, power, and change-of-direction speed but also repeated sprint ability in female young handball players. *J Strength Cond Res*. https://doi.org/10.1519/JSC.0000000000003128.

Cherif, M., Said, M., Chaatani, S., Nejlaoui, O., Gomri, D., & Abdallah, A. (2012). The effect of a combined high-intensity plyometric and speed training program on the running and jumping ability of male handball players. *Asian journal of sports medicine*, *3*(1), 21–28. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3307963/pdf/ASJSM-3-021.pdf.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*, *39*(2), 175–191. https://doi.org/10.3758/bf03193146.

Granacher, U., Goebel, R., Behm, D. G., & Büsch, D. (2018). Stretch-shortening cycle exercises in young elite handball players: Empirical findings for performance improvement, injury prevention, and practical recommendations. In L. Laver, P. Landreau, R. Seil & N. Popovic (Eds.), *Handball sports medicine: basic science, injury management and return to sport* (pp. 537–550). Springer.

Gruić, I. V. D., Bazzeo, M., & Ohnjec, K. (2011). *Situational efficiency of teams in female part of tournament in the world beach handball championship in Cadiz*. 6th International Scientific Conference on Kinesiology, Opatija.

Hammami, M., Gaamouri, N., Aloui, G., Shephard, R. J., & Chelly, M. S. (2019). Effects of combined plyometric and short sprint with change-of-direction training on athletic performance of male U15 handball players. *J Strength Cond Res*, *33*(3), 662–675. https://doi.org/10.1519/JSC.0000000000002870.

Hammami, M., Bragazzi, N. L., Hermassi, S., Gaamouri, N., Aouadi, R., Shephard, R. J., & Chelly, M. S (2020). The effect of a sand surface on physical performance responses of junior male handball players to plyometric training. *BMC Sports Sci Med Rehabil*, *12*, 26. https://doi.org/10.1186/s13102-020-00176-x.

Handball-World.com (2019). IHF-Präsident Moustafa: „Wir wollen das Olympische Programm um Beachhandball erweitern" [Interview]. https://www.handball-world.news/o.red.r/news-1-1-24-115287.html. Accessed 30 June 2019.

Iacono, A. D., Eliakim, A., & Meckel, Y. (2015). Improving fitness of elite handball players: Small-sided games vs. high-intensity intermittent training. *Journal of strength and conditioning research*, *29*(3), 835–843.

Iacono, A. D., Martone, D., Milic, M., & Padulo, J. (2016). Vertical- vs. horizontal-oriented drop jump training: chronic effects on explosive performances of elite handball players. *Journal of strength and conditioning research*, *31*(4), 921–931.

Iannaccone, A., Fusco, A., Skarbalius, A., Kniubaite, A., Cortis, C., & Conte, D. (2022). Relationship between external and internal load measures in youth beach handball. *Int J Sports Physiol Perform*, *17*(2), 256–262. https://doi.org/10.1123/ijspp.2021-0225.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Martino, F., Fiorini, S., & Wisloff, U. (2008). Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. *British journal of sports medicine*, *42*(1), 42–46. https://doi.org/10.1136/bjsm.2007.038497.

Lemos, L., Nevill, A., Duncan, M. J., De Oliveira, V. C., Pino-Ortega, J., Santos, A., & Nakamura, F. (2021). Sport specific skills differentiates performance levels better than anthropometric or physiological factors in beach handball. *Res Q Exerc Sport*. https://doi.org/10.1080/02701367.2021.1902460.

Lemos, L. F., Oliveira, V. C., Duncan, M. J., Ortega, J. P., Martins, C. M., Ramirez-Campillo, R., & Nakamura, F. Y. (2020). Physical fitness profile in elite beach handball players of different age categories. *Journal of Sports Medicine and Physical Fitness*, *60*(12), 1536–1543.

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British journal of sports medicine*, *41*(6), 349–355. https://doi.org/10.1136/bjsm.2007.035113. discussion 355.

Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports medicine (Auckland, N.Z.)*, *40*(10), 859–895. https://doi.org/10.2165/11318370-000000000-00000.

Miyama, M., & Nosaka, K. (2004). Influence of surface on muscle damage and soreness induced by consecutive drop jumps. *J Strength Cond Res*, *18*(2), 206–211. https://doi.org/10.1519/R-13353.1.

Moir, G. L. (2008). Three different methods of calculating vertical jump height from force platform data in men and women. *Measurement in Physical Education & Exercise Science*, *12*(4), 207–218.

Muller, C., Willberg, C., Reichert, L., & Zentgraf, K. (2022). External load analysis in beach handball using a local positioning system and inertial measurement units. *Sensors (Basel)*. https://doi.org/10.3390/s22083011.

Navarro, A., Morillo, J. P., Reigal, R. E., & Hernandez-Mendo, A. (2018). Polar coordinate analysis in the study of positional attacks in beach handball. *International Journal of Performance Analysis in Sport*, *18*(1), 151–167. https://doi.org/10.1080/24748668.2018.1460052.

Pereira, L. A., Freitas, T. T., Marín-Cascales, E., Bishop, C., McGuigan, M. R., & Loturco, I. (2021). Effects of training on sand or hard surfaces on sprint and jump performance of team-sport players: a systematic review with meta-analysis. *Strength & Conditioning Journal*, *43*(3), 56–66. https://doi.org/10.1519/SSC.0000000000000634. https://journals.lww.com/nsca-scj/Fulltext/2021/06000/Effects_of_Training_on_Sand_or_Hard_Surfaces_on.5.aspx.

Prieske, O., Chaabene, H., Puta, C., Behm, D. G., Busch, D., & Granacher, U. (2019). Effects of drop height on jump performance in male and female elite adolescent handball players. *Int J Sports Physiol Perform*, *14*(5), 674–680. https://doi.org/10.1123/ijspp.2018-0482.

Pueo, B., Jimenez-Olmedo, J. M., Penichet-Tomas, A., Ortega Becerra, M., & Agullo, E. J. J. (2017). Analysis of time-motion and heart rate in elite male and female beach handball. *Journal of sports science & medicine*, *16*(4), 450–458.

Ramirez-Campillo, R., Andrade, D. C., & Izquierdo, M. (2013). Effects of plyometric training volume and training surface on explosive strength. *Journal of strength and conditioning research*, *27*(10), 2714–2722. https://doi.org/10.1519/JSC.0b013e318280c9e9.

Ramirez-Campillo, R., Álvarez, C., García-Pinillos, F., García-Ramos, A., Loturco, I., Chaabene, H., & Granacher, U. (2020). Effects of combined surfaces vs. single-surface plyometric training on soccer players' physical fitness. *Journal of strength and conditioning research*, *34*(9), 2644–2653.

Saavedra, J. M., Pic, M., Jimenez, F., Lozano, D., & Kristjánsdóttir, H. (2019). Relationship between game-related statistics in elite men's beach handball and the final result: a classification tree approach. *International Journal of Performance Analysis in Sport*, *19*(4), 584–594. https://doi.org/10.1080/24748668.2019.1642040.

Sabido, R., Hernandez-Davo, J. L., Botella, J., Navarro, A., & Tous-Fajardo, J. (2017). Effects of adding a weekly eccentric-overload training session on strength and athletic performance in team-handball players. *Eur J Sport Sci*, *17*(5), 530–538. https://doi.org/10.1080/17461391.2017.1282046.

Saez de Villarreal, E., Requena, B., & Cronin, J. B. (2012). The effects of plyometric training on sprint performance: a meta-analysis. *Journal of strength and conditioning research*, *26*(2), 575–584. https://doi.org/10.1519/JSC.0b013e318220fd03.

Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Cheour, F. (2016). Effects of plyometric training on physical fitness in team sport athletes: a systematic review. *Journal of human kinetics*, *53*, 231–247. https://doi.org/10.1515/hukin-2016-0026.

Vieira, F., Veiga, V., Carita, A. I., & Petroski, E. L. (2013). Morphological and physical fitness characteristics of under-16 Portuguese male handball players with different levels of practice. *The Journal of sports medicine and physical fitness*, *53*(2), 169–176.

Villarreal, E. S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *Journal of strength and conditioning research*, *23*(2), 495–506. https://doi.org/10.1519/JSC.0b013e318196b7c6.

Zapardiel, J. C., & Asín-Izquierdo, I. (2020). Conditional analysis of elite beach handball according to specific playing position through assessment with GPS. *International Journal of Performance Analysis in Sport*, *20*(1), 118–132. https://doi.org/10.1080/24748668.2020.1718458.