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Original Article

Decline of specific peak jumping power with age in master runners

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Abstract

Background: It is difficult to disentangle the effects of pure ageing from those of disuse. Master athletes, however, provide an opportunity to assess the effects of ageing *per se*, as these people maintain high activity levels during ageing. Methods: We examined 200 female and 295 male master runners over the age of 35 who participated at European and World master championships. Runners were grouped by short, middle and long distance disciplines. Besides a questionnaire about their sports activities, measurements of counter movement jumps on a ground reaction force plate were performed. Specific peak jump power was the main subject, i.e., maximum jump power per body mass. Results: All discipline groups showed an age-related decline in specific jump power when performing counter movement jumps ($p<0.001$). Except for female long distance runners, the amount of decline was the same for all discipline groups ($p<0.001$ to $p<0.01$) for each gender. The results for female long distance runners was highly spread caused by the small number of participants with older age. Conclusions: Our data indicate a decline in specific jump power that is similar to that reported in previous studies. The novelty from our results is the comparison of intra-gender decline. We observed the same amount of decline for all runners participating in different running disciplines.

Keywords: Musculoskeletal Physiology, Mechanography, Master Athletes, Ageing, Muscle

Introduction

The age-related decline in physical performance leads to musculoskeletal frailty and is probably one of the greatest challenges to Western societies in the decades to come. Musculoskeletal frailty leads to loss of independence, an increased risk of falls, and reduces the quality of life[1-3]. It is therefore of the utmost importance to elucidate the physiological mechanisms that lead to musculoskeletal frailty. As well established in and exemplified by paralysed patients, stroke patients or bed rest studies in young healthy subjects, immobilisation leads to muscular atrophy and weakness[4-6]. It is well known that the level of physical activity generally declines with age. Moreover, diseases such as tumours, inflammatory or degenerative diseases lead to a decrease in physical activity, but can also directly ensue muscle atrophy and weakness. In order to understand the interplay of these three traits, (1) senescence as an irreversible biological process, (2) co-morbidity and (3) sedentarism and immobilisation need to be carefully distinguished. Whilst the effects of immobilisation *per se* can ideally be studied in bed rest studies in young healthy volunteers, master athletes constitute an intriguing opportunity to approach the effects of ageing with minimal interference of co-morbidity and sedentarism. Master athletes (often also called Veteran athletes) are athletes older than 35 years that maintain a regular and strict exercise regimen up to very old age. Sedentarism, if at all, should therefore play a minor role in the changes that occur in these Master athletes in relation to age. Moreover, any disease or impairment affecting the musculoskeletal system will immediately disrupt their athletic performance. Hence, Master athletes can be regarded as a positive selection that allows the effects of ageing on the musculoskeletal system without major "cross-talk" by sedentarism or co-morbidity[7]. When studying Master athletes (MA), one must

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	Female			Male		
	SDR	MDR	LDR	SDR	MDR	LDR
Number of participants	98	26	76	126	53	116
Age (SD) [year]	55(13)	59(11)	55(10)	56(13)	59(13)	60(12)
Span [year]	35-86	37-78	37-80	35-90	36-85	40-87
Height (SD) [m]	1.65(0.07)	1.63(0.08)	1.63(0.06)	1.76(0.07)	1.75(0.08)	1.74(0.06)
Weight (SD) [kg]	59(7)	56(8)	56(6)	74(9)	71(11)	68(7)
BMI (SD) $\left[\frac{kg}{m^2}\right]$	22(2)	21(2)	21(2)	24(2)	23(3)	22(2)
ExTime (SD) [h]	8(3)	10(7)	9(9)	8(3)	7(3)	9(5)

Table 1. Study population: Runners were asked for age, height and exercise time per week (ExTime) in hours (SDR: short runners, MDR: mid distance runners, LDR: long distance runners). Weight was measured, age span and BMI were calculated. Significant differences were marked. Significance levels: ***(p<0.001), **(p<0.01).

therefore be prepared to find that such effects that have been thought of as being inherent to the ageing process do not occur amongst MA. As an example, we have recently reported that, opposed to the general population as published in the literature[8-14], the age-related decline in oxygen uptake kinetics is mitigated in MA specialized in sprint running, and even absent in Master endurance runners[15]. As to the decline in anaerobic muscle power, we have recently found in a cross-sectional study in over 200 healthy and physically competent subjects between 18 and 88 years of age that the peak jumping power specific to body weight (P_{Spec}) declines by more than 50% from age 20 to age 80[16]. This was in so far surprising, as in the same population, there was no age-related change in calf muscle cross-section. It seems, thus, as though a decline in muscle power output would be a key factor in musculoskeletal ageing. Given that musculoskeletal frailty, as identified by the risk of falls, is more prevalent in women than in men, we wished to elucidate gender differences in jumping performance between male and female Master runners.

Materials and methods

Study Population

The study population was recruited during the European Veteran Athletics Championships 2002 and 2004 (Potsdam, Germany, August 15-25 and Arhus/Randers, Denmark, July 22-August 1, 2004) and World Master Athletic Championship 2005 (San Sebastian, Spain, August 22-September 3, 2006). Athletes were included in this study if they participated in running disciplines. All athletes with injuries or diseases at the moment of test were excluded. The study was approved by the Ethics committees in Aarhus and San Sebastian. All participants gave their informed consent before inclusion into the study.

Study Design

The present study is a cross-sectional study with an option of longitudinal follow-up. After enrolment, participants had to fill out a questionnaire. Personal data like age, height, disciplines at this championship and exercise time per week have been collected. Afterwards, a two leg jump test was performed on a force platform (Novotec Medical, Pforzheim, Germany). Runners were classified according to their self-rated best discipline (SBD) as short (<=400 m), medium (800-1500 m) and long (>1500 m) distance runners. Since we were interested in runners with high levels of performance, the recruitment focused on participants of the finals. Personal invitations to participate were made after these events. Measurements were taken at the earliest 1 hour after the last sprinting event, 2 hours after the last medium distance event, or 4 hours after the last long distance event the subjects had participated in.

Jumping Mechanography

Whole body neuromuscular function was assessed by jumping mechanography[17]. These measurements of mobility are reliable for frail patients as well as for Master runners[7,16]. Measurements were performed as counter movement jumps with hands allowed to move freely. Participants were instructed to jump as high as possible. The test was performed on a ground reaction force plate (Leonardo, Novotec Medical, Pforzheim) using an analog-digital converter NI-DAQ card and a personal computer.The system measures vertical ground reaction force. All further calculations follow the described recipe in Davies et al. and Cavagna et al.[18,19]. A more detailed recipe has not been published yet[20]. Vertical acceleration is calculated by dividing the force by body mass and subtracting the gravitational acceleration. Numeric integration of acceleration yields vertical velocity, the numeric integration of velocity gives the height change of the centre of mass (jump height is the difference between start height and maximum height). Multiplying force

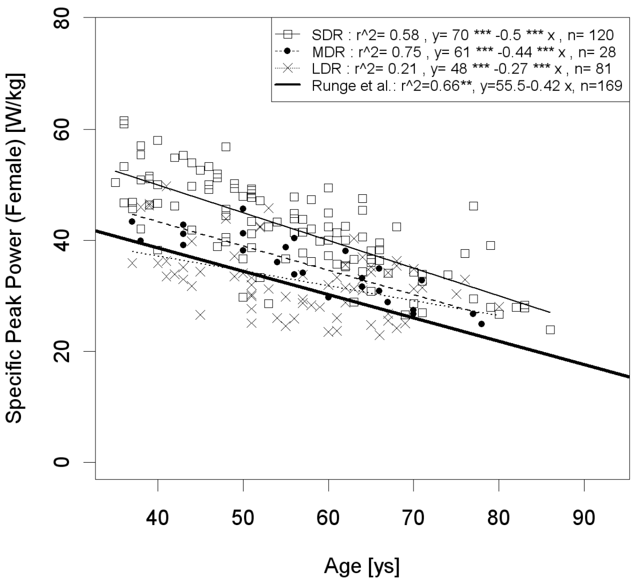

Figure 1. Age-declined P_{Spec} for female runners shows linear decrease for all disciplines. Short distance runners (SDR) and mid distance runners (MDR) have the same slope but different intercepts which starts on a higher base level for SDR. Long distance runners (LDR) statistics have a huge spread (R^2=0.23) and is therefore not comparable in slope but significant below SDR and MDR. Significance levels for slope and intercept: ***(p<0.001), **(p<0.01).

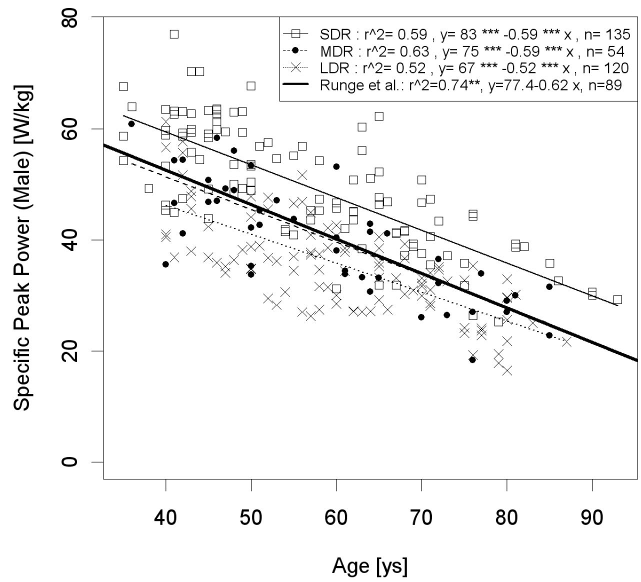

Figure 2. Age-declined P_{Spec} for male runners shows linear decrease for all disciplines. There is no significant difference in slope between all groups but in intercept. That means that short distance runners (SDR) start on a higher level than mid distance runners (MDR) who in turn start on a higher level than long distance runners (LDR). Significance levels for slope and intercept: *** (p<0.001), ** (p<0.01).

by velocity yields vertical power [W]. Primary outcome parameters are maximum force per body mass (F_{Spec} [N/kg]) and maximum power per body mass (P_{Spec} [W/kg]). Measurements were computed by the manufacturer's Leonardo software in its version 3.07. Analysis was acquired by a proprietary developed software (GrfpAnaylsis in its version 0.60).

Computations and statistical analyses

Statistical analysis was carried out with the open source statistical program "R-project" in its version 2.4.1[21,22]. An analysis of variance was used to calculate linear increase and decay. Comparison of linear models (intra and inter gender) was calculated using ANCOVA. Study population was compared using two sample Wilcoxon test (Mann-Whitney test). Generally, linear models were assumed as long as higher order polynomial models did not increase R^2 and residual plots satisfy statistical boundary conditions. A P-value <0.05 was considered for statistical significance.

Results

Study Population

200 women and 295 men participated in the study. Both males and females were divided into three subgroups according to their SBD. The anthropometric measures of the study population can be seen in Table 1. The male long distance runners (LDR) turned out to be slightly older than the short distance runners (SDR) (60 for LDR 56 y for SDR, p=0.01), for all other groups there was no significant difference. As expected, sprint runners were heavier and had a higher BMI than mid distance runners (MDR) and LDR for both genders. No significant difference could be seen in height. With regard to exercise times, female SDR trained less than MDR and LDR and for the men, the MDR trained as much as the SDR. MDR and SDR trained less than LDR.

Jumping Mechanography

Comparison of all groups (intra-gender)

Significant correlations were found between P_{Spec} and age when investigated in both, the entire sample of the male and the entire sample of female, runners (Figures 1 and 2). In male runners', P_{Spec} declined linearly with age for all runners groups (Table 2). No differences in slope were found, but significant difference in intercept (Table 3). SDR had higher P_{Spec} than MDR (p<0.001) for all groups of runners who in turn had greater P_{Spec} than LDR (p<0.001) (Table 4). Slightly different results were obtained for female runners. The decline with age was linear in all subgroups, but contrary

		P_{Spec} - Slope Value (SE) $\left[\frac{W}{kg}/year\right]$	P(>|t|)	P_{Spec} - Intercept Value (SE) $\left[\frac{W}{kg}\right]$	P(>|t|)	R^2	N
Female	**SDR**	-0.51(0.04)	***	70(3)	***	0.58	98
	MDR	-0.47(0.06)	***	63(3)	***	0.75	26
	LDR	-0.29(0.07)	***	49(4)	***	0.21	76
Male	**SDR**	-0.59(0.05)	***	83(3)	***	0.58	126
	MDR	-0.58(0.07)	***	74(4)	***	0.62	53
	LDR	-0.51(0.05)	***	66(3)	***	0.50	116

Table 2. Significant linear dependencies are found for all disciplines for female and male (SDR: short distance runners, MDR: mid distance runners, LDR: long distance runners). Slope and intercepts are highly significant, spreading is small or acceptable except for female LDR. Results: Significance levels: ***(p<0.001).

		P_{Spec} - Slope		P_{Spec} - Intercept	
		MDR R^2 (P>|t|)	**LDR** R^2 (P>|t|)	**MDR** R^2 (P>|t|)	**LDR** R^2 (P>|t|)
Female	**SDR**	0.65	0.62 (***)	0.65 (***)	0.60 (***)
	MDR	ns	0.36	ns	0.34 (*)
Male	**SDR**	0.67	0.72	0.67 (***)	0.72 (***)
	MDR	ns	0.57	ns	0.57 (**)

Table 3. Significant differences of P_{Spec}/Age in correlation of slope and intercept between runners' groups using ANCOVA (SDR: long distance runners, MDR: mid distance runners, LDR: long distance runners). There is no significant difference between slope intra-gender groups except for female SDR and LDR. On the opposite site, differences in intercepts are highly significant. Significance levels: ***(p<0.001), **(p<0.01), *(p<0.05), "ns: not significant" (p<1).

to the male runners, a difference in slope could be seen between the LDR and SDR with LDR declining slower than SDR. As shown in Table 2, the span of P_{Spec} for female LDR was very large which makes it difficult to detect any difference. The difference in intercept was as significant as for the male runners.

Effect of gender

No gender effect was found in slope for SDR and MDR. However female LDR depicted smaller decline of P_{Spec} with age than male LDR. Gender differences in intercept were found for all 3 groups (Table 5) with male athletes depicting larger intercepts (Table 6).

Physical activity

No significant correlation was observed neither between physical activity and specific jump power nor physical activity and age or a combination of both.

Discussion

Cross-sectional studies are naturally biassed by selection of participants. We decided to include top Master runners at European or world championships only because of an assumed higher difference to the non-athletic average population. In both genders, jumping power was higher for SDR than for MDR who in turn showed higher jumping power than LDR. This result is not surprising and can be explained by a different fibre type distribution in different types of athletes. Sprinters have more type II fibres which are the fast fibres. It is this type of muscle fibre which can produce the highest power because of the fast production of energy through anaerobic energy production. Type II fibres are able to produce a high amount of power fast as can be seen in sprint disciplines. Thus, in a jump test which naturally requires a high amount of power, people with type II muscle fibres have an advantage[23]. It can be seen in this study that this advantage of sprint runners remains until old age. When comparing these results to the results of Runge et al.[16] who

	A	B	A≠B	A<B	A>B
Female	SDR	MDR	***	ns	***
	SDR	LDR	***	ns	***
	MDR	LDR	ns	ns	#
Male	SDR	MDR	***	ns	***
	SDR	LDR	***	ns	***
	MDR	LDR	**	ns	**

Table 4. Wilcoxon test for male P_{Spec}/Age (SDR: long distance runners, MDR: mid distance runners, LDR: long distance runners). There is a highly significant difference between SDR and MDR, SDR and LDR as for MDR and LDR in males and females. P_{Spec} for SDR is higher than for MDR and LDR, for MDR it is higher than for LDR. Female LDR show no significance at all. Significance levels: ***(p<0.001), **(p<0.01), # (p<0.1), "ns: not significant" (p<1).

		P_{spec} - Slope R^2 (P>ltl)			P_{spec} - Intercept R^2 (P>ltl)		
		Male			**Male**		
		SDR	**MDR**	**LDR**	**SDR**	**MDR**	**LDR**
	SDR	0.63	ns	ns	0.63 (***)	ns	ns
Female	**MDR**	ns	0.65	ns	ns	0.65 (***)	ns
	LDR	ns	ns	0.44 (***)	ns	ns	0.41 (***)

Table 5. Significant differences in correlation of P_{Spec}/Age slope and intercept between genders using ANCOVA (SDR: long distance runners, MDR: mid distance runners, LDR: long distance runners). There is no significant difference for P_{Spec} between SDR and MDR in slope but highly significant in intercept. Same is for male LDR. Female LDR show significances in slope and intercept. Significance levels: ***(p<0.001), **(p<0.01), "ns: not significant" (p<1).

	$P_{spec, Female} \neq P_{spec,Male}$	$P_{spec, Female} < P_{spec, Male}$	$P_{spec, Female} > P_{spec, Male}$
SDR	***	***	ns
MDR	#	*	ns
LDR	#	*	ns

Table 6. Wilcoxon test for gender PSpec/Age (SDR: long distance runners, MDR: mid distance runners, LDR: long distance runners). There is a significant higher Pspec for males than for females in SDR, MDR and LDR. Significance levels: *** (p<0.001), * (p<0.05), #(p<0.1), "ns: not significant" (p<1).

studied the decline of jumping power with ageing in a healthy population, it was observed that the normal population reached about the same or even higher P_{Spec} than the LDR in females and MDR in males. This can also be explained by the higher proportion of slow fibres in MDR and LDR, contrary to the 'mixed' distribution of the normal population.

Comparing the decline of jumping power with age, it could be seen that P_{Spec} declined linearly with age in all subgroups and genders. For male runners, no difference in slope could be found, so all runners had the same amount of decline with ageing. Due to different intercepts, SDR kept their jumping power longer than MDR or LDR. The picture is different for female runners. Amongst them, a difference in decline could be found between LDR and SDR with LDR losing less than SDR with advancing age. This could on the one hand be caused by high spread found for the female LDR. The results are similar to results by Grassi et al.[24] who found a linear decline in male and female master runners Pspec values. Pearson et al.[25] observed linear decline in male master weightlifters' lower limb power. Wiswell et al.[26] on the other hand observed a significant but non-linear decline in running performance; the non-linearity is caused by few data in older ages (>60). Hawkins et al.[27] found a decline in lean body mass performance, but not in all ages and an age-related decline in running performance. Concerning the muscle fibre type distribution, Korhonen et al.[28] and Hawkins et al.[29] described a decline in muscle fibre type II area with age but no significant change in type I fibres and a decline in lean body mass. That supports our results of decline in lower limb power with age caused by muscle fibre type redistribution. In contrast to Korhonen et al.[28] we did not observe a decrease in exercise time per week with age, and in our study it is thus unlikely that the decline in specific force and power is caused by a decline in physical activity. The focus of our questionnaire was on common state of health of the participants and not on physical activity. We recommend a more detailed questionnaire for future studies concerning this parameter.

All of our results have been calculated from a cross-sectional study. In future studies of Master athletes many more female athletes over 80 years have to be measured. That is quite difficult due to few participant numbers. For further information about muscle power performance with age longitudinal data is necessary. Measurements of jumping mechanography are applicable to Master athletes without disturbing their preparation for competition. It is hoped that there will be further research using this technique to determine the effects of physical activity in old age.

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