IBoaT-Report 3.6.2

Fit & Sail Project

Project Report (abridged version): Results of Load Tests on Elderly Sailors on Board of Cruise Sailing Yachts

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September 2009

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Contents

1 Preliminary Remarks and Acknowledgements

The “Fit & Sail” research project, which examines the physical and mental effects of cruise sailing on elderly people, was initiated in 2005 in cooperation with the Bundesverband Wassersportwirtschaft e.V. (BVWW, German Marine Federation) in Cologne, the Institut für Sport und Sportwissenschaften (ISS, Institute for Sport and Sport Science) at the University of Kiel and the Institut für Boots-Tourismus (IBoaT, Institute for Boat Tourism) in Bonn. The project was supported by the French “Connect to Sailing task force” of the Fédération Française de Voile (FFVoile, French Sailing Federation) in Paris.

The project has the following objectives:

1. To provide sports medicine observations of the physical and mental loads experienced by male and female test persons of different ages (with a particular focus on the 60+ age group) during various typical activities on board cruise sailing boats, both under sail and under motor power, and the collection and evaluation of the resulting data. To evaluate the findings in respect of age-related and gender-related load levels and their interpretation in terms of health, sport science and training science.

2. To undertake the comparative experimental testing of innovative design and equipment-technology-related measures and their ergonomic options for the reduction of load peaks, the reduction of thresholds of use and improvement of the handling and safe operation of cruise sailing ships, particularly by older male and female sailors.

The work on this part of the “Fit & Sail” project was divided up as follows:

- The task of coordinating the project was assigned to Dr Wolf-Dieter Mell, Institut für Boots-Tourismus (IBoaT).
- The sport medicine tests were carried out by Ms Ingeborg Sauer under the supervision of Professor Burkhard Weisser at the Institut für Sport und Sportwissenschaften (ISS) at the University of Kiel.
- The development work for the “ComfoDrive” subproject, i.e. the experimental testing of the concept for the simplification of manoeuvring under motor power, were carried out at the Institut für Boots-Tourismus (IBoaT) in close cooperation with the companies BCE-Elektronik GmbH (Lemgo) and ancora Marina (Neustadt/Holstein).
- The Bundesverband Wassersportwirtschaft e.V. (BVWW) assumed responsibility for the formal management of the project in 2006. The

project budget was managed by the BVWW office in Cologne. The BVWW Board and office successfully carried out the publicity work for the project and looked after the sponsors.

An initial summary of the sports science results and development work on the “ComfoDrive” subproject were presented to the public at a special stand at the “boot 2008” trade fair with the support of Messe Düsseldorf GmBH.

The following craft and equipment were made available to the “Fit & Sail” project in late 2008 by the sponsors:

- a Hanse 341 cruise sailing boat from HanseYachts AG Greifswald for the implementation of the sports medicine tests;
- a small Neptun 22 cabin cruiser from the Institut für Boots-Tourismus Bonn for pilot studies and technical tests;
- cruise equipment for the Hanse 341 (from life jackets, ropes and fenders to sea charts and crockery) from A.W. Niemeyer GmbH Hamburg;
- extensive services from ancora Marina Neustadt in Holstein for the necessary conversion and maintenance work;
- bow thruster and electronic engine remote control from Volvo Penta Central Europe GmbH Kiel for the construction and testing of prototypes of the “ComfoDrive” system (see below);
- funding from the Donation Programme of the International Marine Certification Institute (IMCI) in Brussels as a contribution towards material and personnel costs;
- personnel and material from the three project partners in the course of the implementation of the project.

We would like to thank all of the sponsors sincerely for their generous support in the form of materials, services and funding for the “Fit & Sail” project.

The detailed project report is published in German as IBoaT-Report 3.6 (ISSN 1860-7888), an abridged version in German as IBoaT-Report 3.6.1 and an abridged version in English as IBoaT-Report 3.6.2.

2 Starting Position and Concept

2.1 Starting position and project assignments

IBoaT published a pilot study in September 2005 which presented and analysed for the first time long-term measurements of the cardiovascular load experienced by an elderly test person during a sailing trip lasting several weeks (see IBoaT-Report 3.1).

The preliminary findings of this study, in particular the references to particular load situations on board which, with the increasing age of the sailors, could possibly be perceived as excessive and could, therefore, be used as reasons for giving up active yachting and boating, coincided with the observations of the Bundesverband Wassersportwirtschaft (BVWW) from 2000 to 2004. According to these observations, on the one hand, an increasing “proportion of seniors” (at least one third of boat owners were older than 60 years) could be observed among sailors while, on the other hand, yacht owners of around 70 years of age, in particular, were giving up their boats and active sailing spontaneously and at short notice.

A study carried out by the Forschungsvereinigung für die Sport- und Freizeitschifffahrt (Research Association for Sport and Leisure Boating) in 2008 confirmed and refined these observations: the following conclusions arise from the study “Strukturen im Bootsmarkt” (“Structures in the German Boat Market”) (FVSF Research Report No 1) and from additional interviews:

- Of the approximately 500,000 Germans who own motor-powered or sailing boats, around 360,000 are owners of motor or sail yachts (boats with cabins and overnight facilities). Of these 45 % are over 60 years of age.
- 95 % of the yacht owners are men, however in over 70 % of cases the crews consist of two people, usually the owner and his or her partner.
- From the age of 65, these owners increasingly consider retiring from active participation in water sports. Around 50 % of this age group actually give up at between 70 and 75 years of age.
- The seniors rarely retire for health or financial reasons; retirement is usually justified with reference to general categories such as “age” or “too tiring” (and in many cases with reference to a partner’s wishes).

These observations of elderly yacht owners are further reinforced by the following general insights from the fields of demographics and gerontology:

1. The projections for population development in Germany (see Fig. 2-1) show that the number of 20-59 year-olds will decline by approximately 30% in the years to come while the size of the 60-79 age group will increase significantly.

   Therefore the traditional “age pyramid” (a lot of young people and fewer older people) will become inverted by the middle of the century. These trends also highlight the increasing economic significance of seniors.

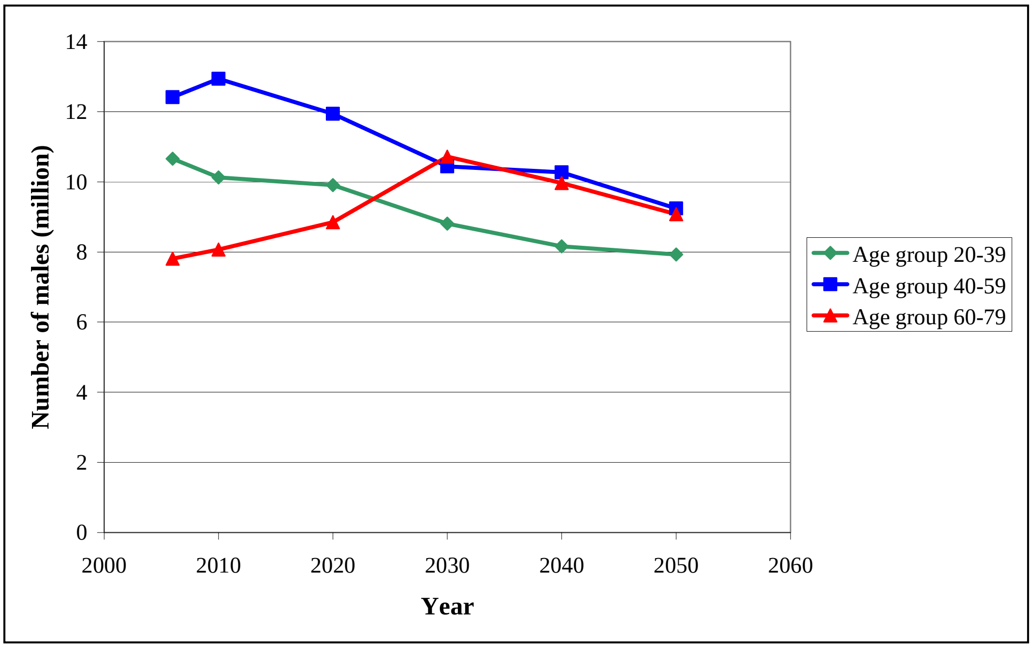

Fig.: 2-1: Population development in Germany: number of men in the 20-39, 40-59 and 60-79 age groups for the years 2006-2050
(Source: Statistisches Bundesamt 2009)

2. Sports science tests of the age-dependency of physical fitness (see Fig. 2-2) show, first, a general decline in physical strength from the age of 30 by an average of 8-10 % per decade and, second, that the physical strength of women is approximately ⅓ lower than that of men.

   The following diagram clearly shows that on-board physical activities (e.g. setting the sails, hauling the sheets, hauling the anchor) which gradually become “too tiring” for a 70-year-old man are often too much for a 40-year-old woman.

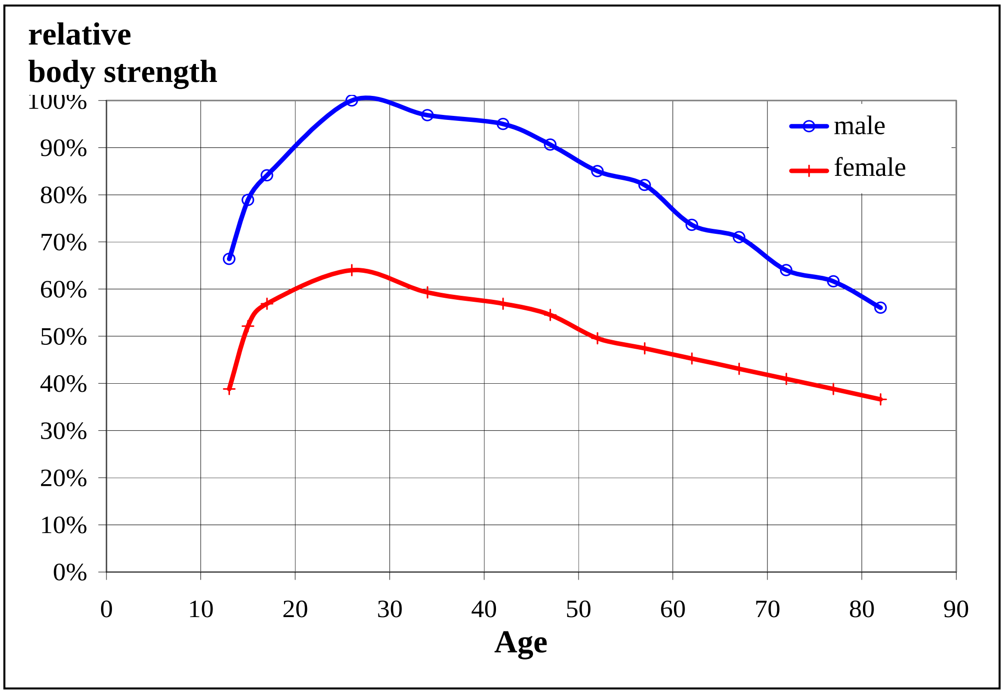

Fig.: 2-2: Average age-related development of upper body and arm strength in men and women
(Source: IBoaT derived from the requirements for the German Sports Badge)

3. Gerontologists suggest that the average state of health of elderly people will probably continue to improve as a result of the progress made in medicine and medical technology. As a result, an increasing proportion of people will reach an advanced to very advanced age in a reasonable state of health. These "healthy seniors" will want to organise their old age more autonomously and actively than previous generations.

The preliminary tests gave rise to the following assignments for the initial research section of the project:

1. Sports science methods were to be used to identify:

   a) the level of physical fitness that may be assumed for elderly male and female sailors as compared with the population average;

   b) the sequences of movement and activities on board a larger sailing yacht that generate particular loads and how big these loads are.

2. It was also planned to examine technical solutions, with the help of which the manoeuvring of a sailing yacht under motor could be made easier and more safe. Suitable concepts were to be implemented as prototypes and tested.

2.2 Interpretation of the preliminary studies

An important result of the preliminary studies was the observation that the heart rates measured, e.g. with a heart rate monitor, under physical or mental loads are a good indicator of the size of this load.

A second important aspect is the sports medicine observation that the “relative heart rate”, i.e. the ratio between the measured and individual maximum heart rate” (HR_{max}), can be used as a meaningful indicator for the subjectively perceived intensity of the load.

Maximum heart rate is the number of heart beats per minute which an individual can reach at maximum physical exertion. Maximum heart rate is an individual parameter and can be determined by ergometry. Particularly important in this context is the fact that individual maximum heart rates declines with the age of the person.

The standard method for the estimation of maximum heart rate as a function of age is based on the formula:

$$HR_{max} = 220 - \text{age} \quad \text{(men).}$$

The measured data of a load, which were converted to the relative heart rates, can be illustrated for the subjectively perceived load with the help of a modified Borg scale:

Load categories (modified Borg scale):	Relative heart rate
Slightly tiring	50-60% HR_{max}
Somewhat tiring	60-70% HR_{max}
Tiring	70-80% HR_{max}
Very tiring	80-90% HR_{max}
Extremely tiring	90-100% HR_{max}

The following diagram illustrates this transformation, average values of 60 % and 80 % HR_{max} are assumed for the aerobic and anaerobic thresholds.

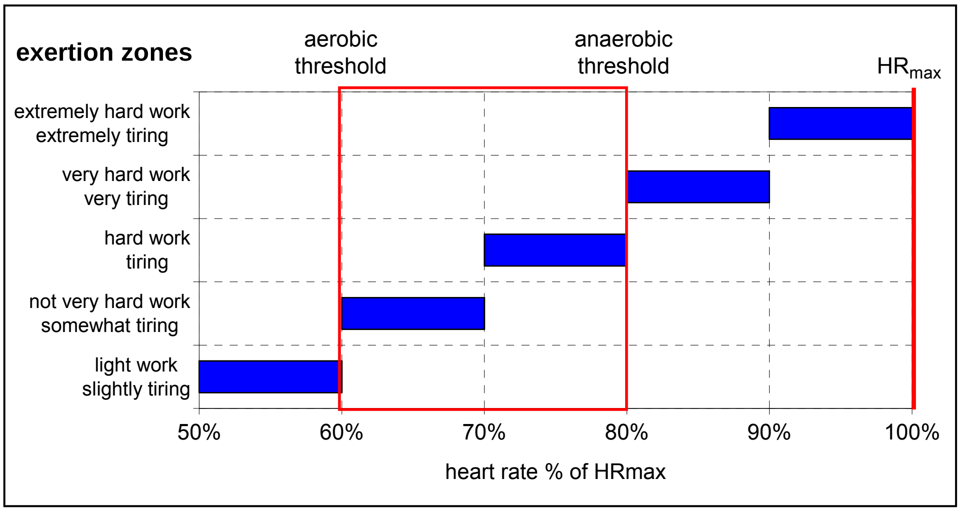

Fig.: 2-3: Load categories for the modified Borg scale as a function of the relative heart rates

Based on the observation – which was confirmed by the tests – that the heart rates measured during on-board activities depend on the activity, but not the age of the actor, and on the cardiovascular "norm", according to which a person's maximum heart rate declines by around 10 bpm per decade with increasing age, it may be concluded that the relative heart rate (in % HR_{max}) required for the completion of an activity rises with increasing age and with it the subjectively perceived exertion.

It is possible to calculate age projections for the predicted levels of exertion based on this.

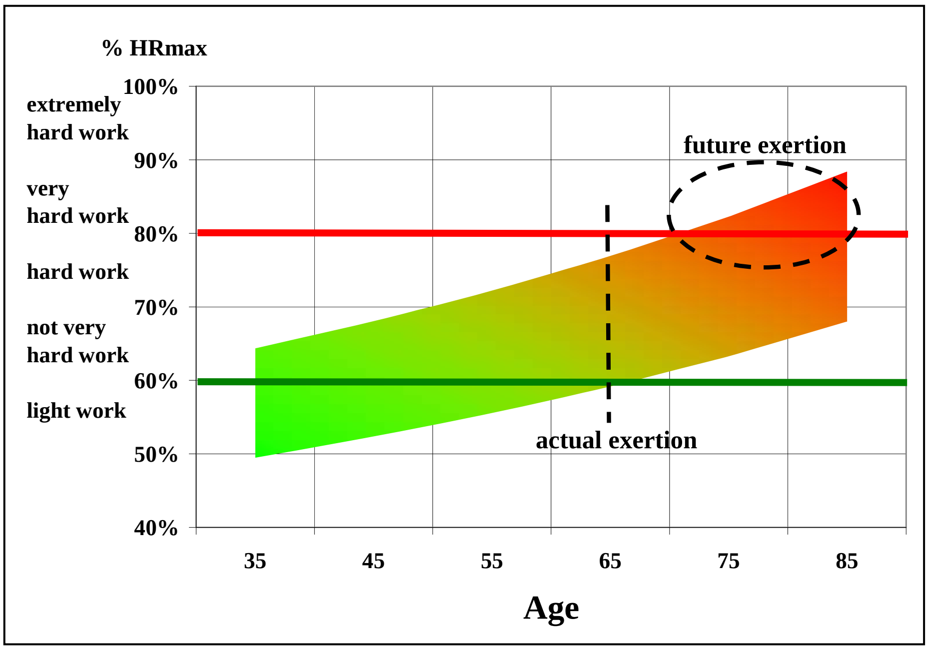

Fig.: 2-4: Example of age projection for a given load

The following important observation arises from the concept of the age projections:

- On-board activities – involving physical or mental loads – which are perceived as hard work by a 65-year-old sailor (heart rates of around 120 bpm) are likely to become very hard work for him by the age of 75 at the latest and constitute, therefore, a motive for the avoidance of this activity.

3 Results of the Sport Medicine Tests

As part of the sports medicine tests, 36 male cruise sailors in the age range 53 to 86 years and (unfortunately only) six women in the age range 52 to 61 years were tested during a series of typical manoeuvres with respect to the resulting exertion symptoms – both in the laboratory and on board a cruise sailing yacht – for their general physical strength, their arm strength and their coordination ability. In addition to this, the scope of weekly sporting activity and number of sea miles covered per year were also surveyed for each test subject and the weather conditions on board, in particular the wind force, were also documented.

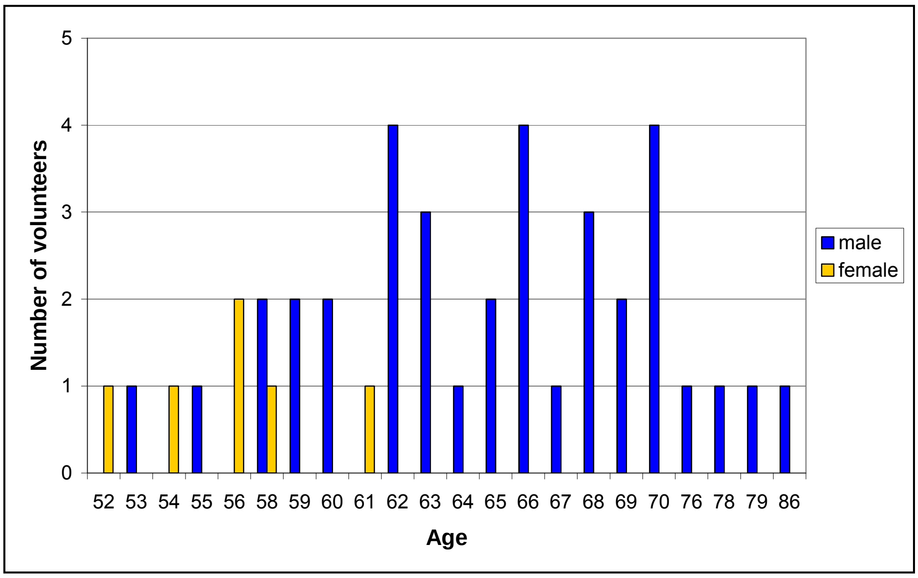

Fig.: 3-1: Age range of the test subjects

Time series of both the subjects' heart rates and blood pressure were measured and evaluated as load indicators for the on-board activities.

The main findings:

3.1 Laboratory measurements

1. The physical fitness levels of the male sailors studied did not differ from the average levels for the healthy population.

   - At an age-independent average of 1.5, the fitness status of the 36 male test subjects (average age 66) in the PWC 130 (physical working capacity) bicycle ergometry test was exactly average.

     As opposed to this, at PWC 130 values of between 1.5 and 2, the fitness of the few female test subjects was above average.

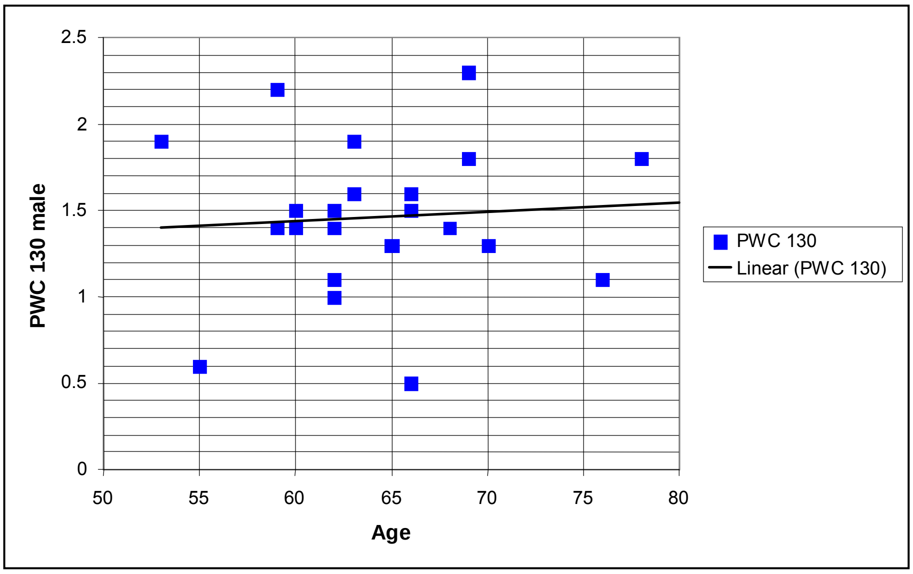

Fig.: 3-2: Fitness of the male test subjects at PWC 130

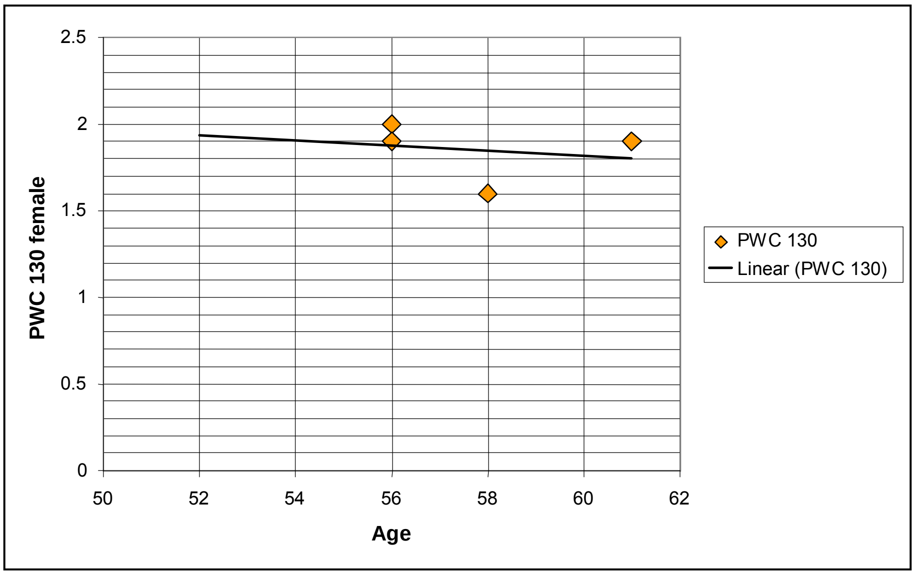

Fig.: 3-3: Fitness of female subjects at PWC 130

- For this average fitness of 1.5 points PWC 130, the test subjects participated in sporting activities for two to three hours per week on average. The correlation between PWC 130 and weekly sport showed that each additional hour of weekly sporting activity increases the performance of the cardiovascular system by around 7 %.

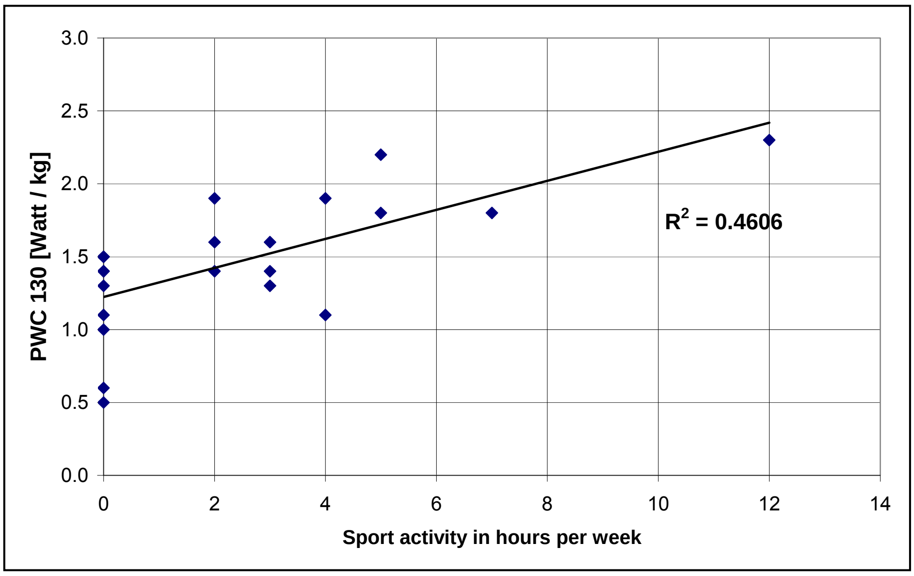

Fig.: 3-4: Correlation between physical exertion at a heart rate of 130 bpm and weekly sporting activity

- At an average value for systolic blood pressure of approximately 130 mmHg for 55-year-olds and an age-related increase of around 10 mmHg/decade, the resting blood pressure of the test subjects was in the inconspicuous range, taking into account mild age-related hypertension.

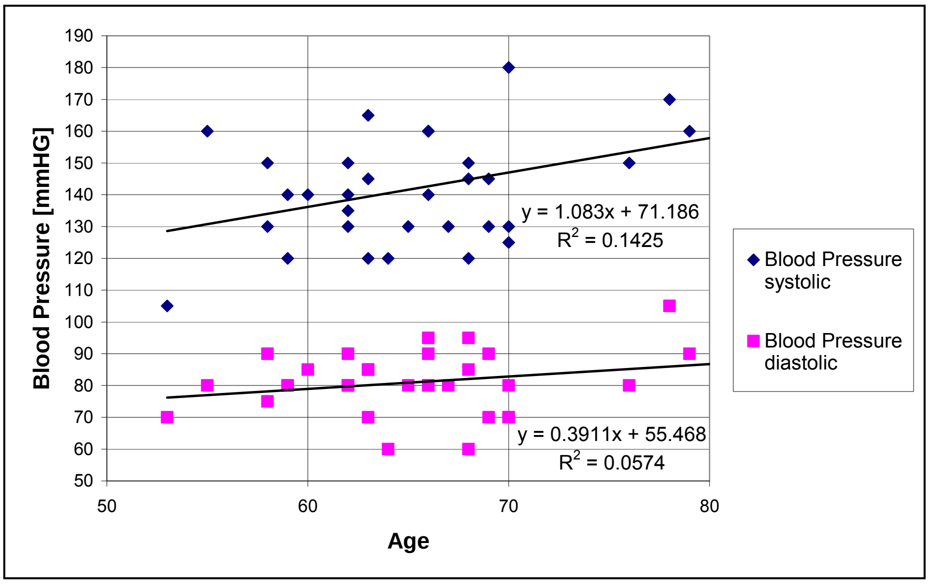

Fig.: 3-5: Resting blood pressure of male test subjects

2. The average recorded maximum arm strength of biceps and triceps measured for the male subjects in the laboratory were:

   - biceps: 30 kg
   - triceps: 22 kg

   with a clear age-related decline of around 6 % per decade.

   The arm strengths of the women were around one third lower than those of the men.

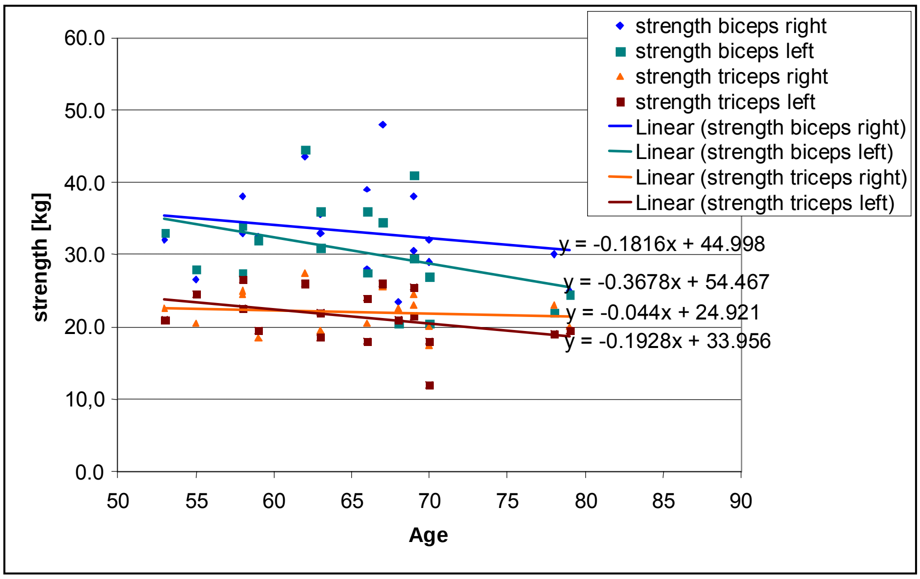

Fig.: 3-6: Upper-arm muscle strength of the men: age-dependency

3. The measurements on coordination ability, in particular static balance (standing on one leg with eyes closed) revealed two trends:
   - the ability to balance declines clearly with age;
   - a greater level of fitness (PWC 130) also significantly improves the ability to maintain static balance.

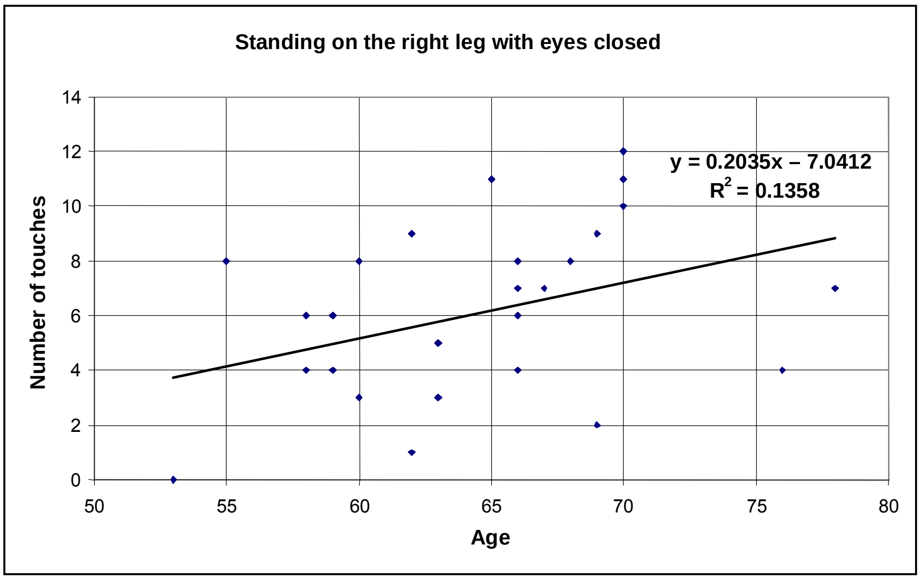

Fig.: 3-7: One-leg stand (right leg) with eyes closed: number of times foot touches the ground as a function of age

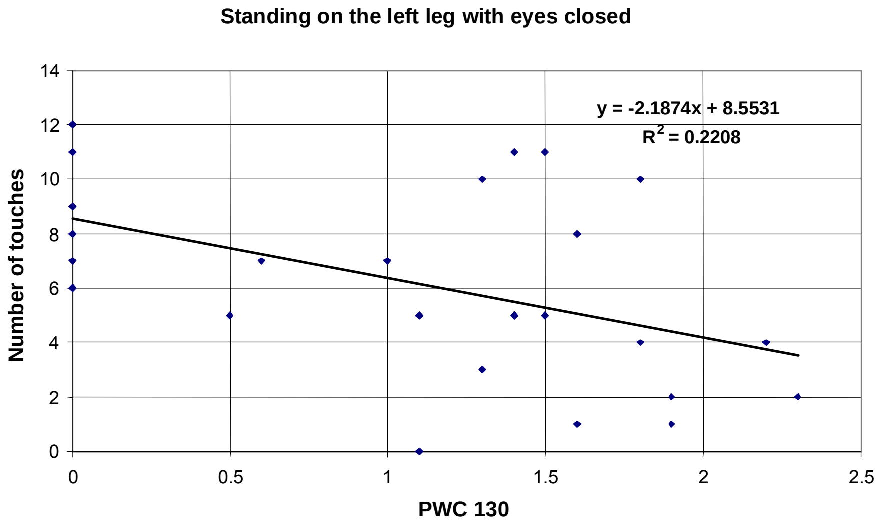

Fig.: 3-8: One-leg stand (left leg) with eyes closed: number of time foot touched the ground as a function of fitness

3.2 On-board measurements

1. For the on-board activities, each test subject's heart rate was tested every five seconds with the help of a heart rate monitor and the blood pressure was taken every 10 minutes using an automatic blood-pressure monitor. The average maximum value in the time series per manoeuvre was used as the parameter here.

   In the evaluation, the activities/manoeuvres were differentiated on the basis of whether they mainly involved physical loads for the test subjects (e.g. setting the sails, controlling the sheet during turns and jibes) or whether they mainly generated mental (stress) loads for the helmsman (e.g. casting off/mooring under motor power, man overboard manoeuvre).

2. The following diagram presents an overview of the measured heart rates as average values for all test subjects ± standard deviation and the load categories (Borg scale) for the activities:

   - setting the mainsail without assistance,
   - turn, test subject at the mainsheet,
   - jibe, test subject at the mainsheet,
   - setting the foresail,
   - running from the stern to the bow and back,
   - casting off under motor power,
   - turn, test subject at the helm,

- jibe, test subject at the helm,
- man overboard, test person at the helm
- hauling the mainsail, test subject coordinates the manoeuvre,
- mooring under motor power.

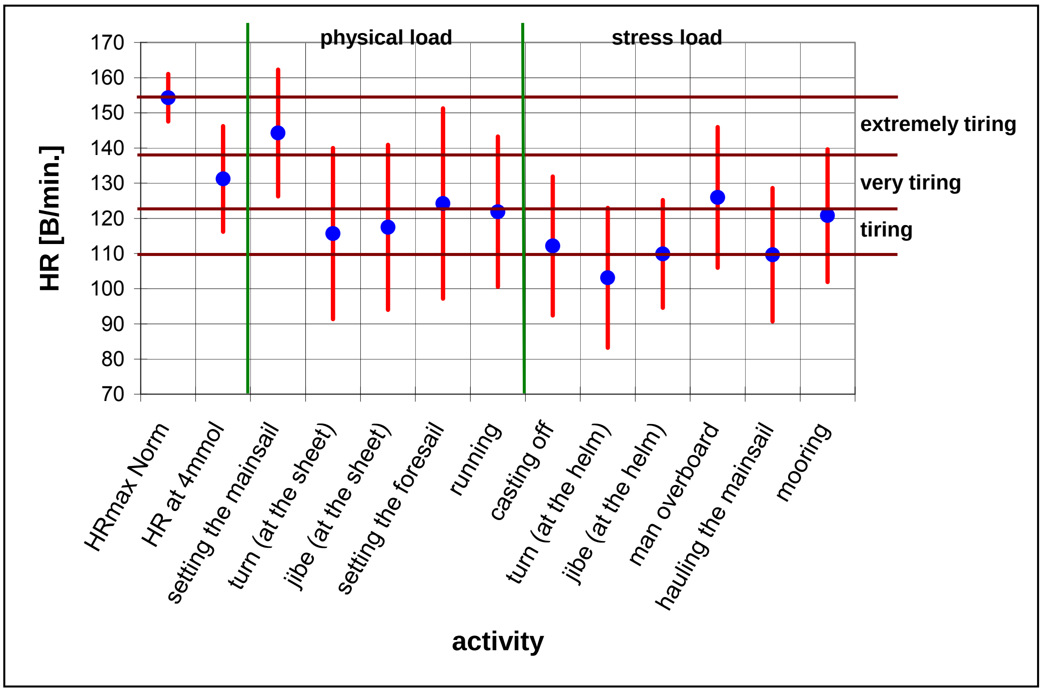

Fig.: 3-9: Spread of physical and stress loads on board (men, average value ± standard deviation, with load categories)

3. Heart rate emerged in the tests as a parameter that is largely dependent on the concrete physical or mental load and independent of the age of the test subject.
4. In the case of the blood pressure, the expected rise in systolic blood pressure with heart rate was observed with an average rate of increase of around 5 mmHg/10 bpm.

   It was interesting to note that in the case of stress-induced increases in heart rate, the corresponding increase in systolic blood pressure was significantly higher than in the case of physically induced increases.

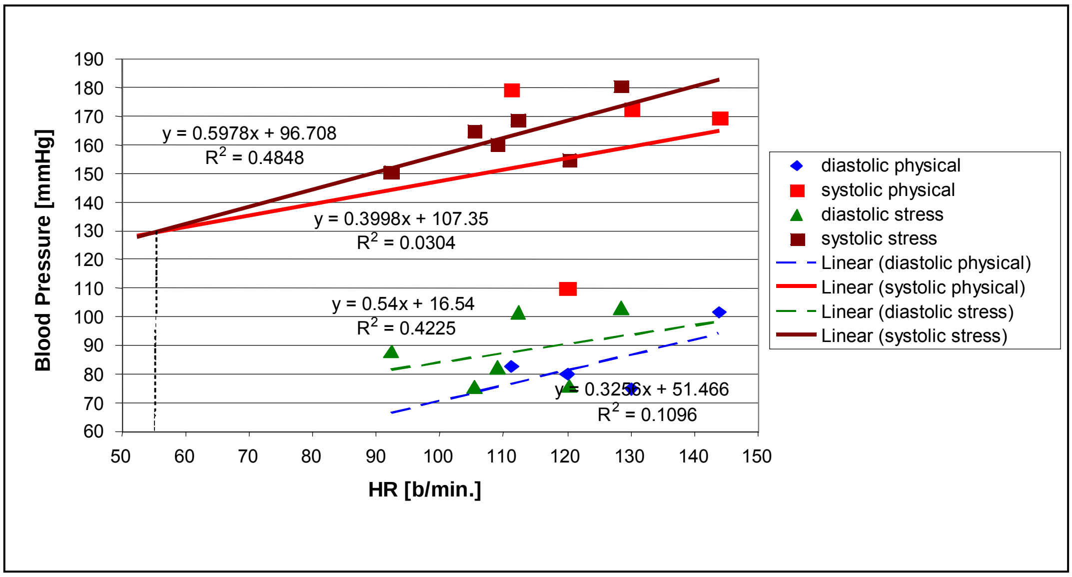

Fig.: 3-10: Average value per manoeuvre and trends in blood pressure values as a function of heart rate for the male test subjects, divided according to physical exertion (p) and mental stress (s)

5. Of the physical loads tested, as expected, setting the sails (by winch) proved particularly hard work for the test subjects and gave rise to heart rates of 130-160 bpm (80-100% HR_{max}, “very tiring” to “extremely tiring”). However, the other physical tasks involving the ropes and sheets also tended to push the 60+ age group (depending on individual and external parameters) strongly to very strongly and sometimes to the limit of their capacities.

6. The observations of the mental loads (including mooring under motor power and man overboard manoeuvres) produced two important pieces of information:

   - in individual cases, the stress load can give rise to heart rates that extend to the upper limit;
   - the test subjects can be divided into two groups based on their reaction to stress loads:
     - the “relaxed group” processed the request at an unexerted heart rate of less than 110 bpm. (Manoeuvre “moor under motor power”: 55% of the test subjects),
     - the “stressed group” reacted with elevated heart rates of between 120 and 160 bpm. (Manoeuvre “moor under motor power”: 45% of the test subjects).

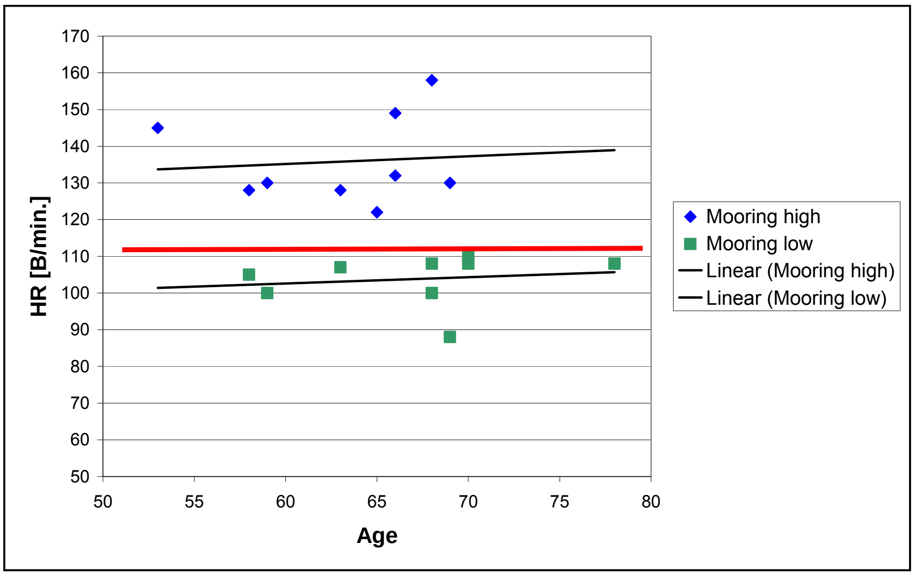

Fig.: 3-11: Heart rate as a function of age, two groups with high and low stress levels: mooring under motor power

7. The heart rate which was measured under both physical and mental loads tends to be dependent on the fitness of the test subjects:
   - In the case of a heavy physical load (e.g. "setting of the mainsail") the tendential link between heart rate and PWC 130 is:

     a higher (lower) level of PWC130 fitness of 0.5 points reduces (increases) heart rate by approximately 8 bpm.

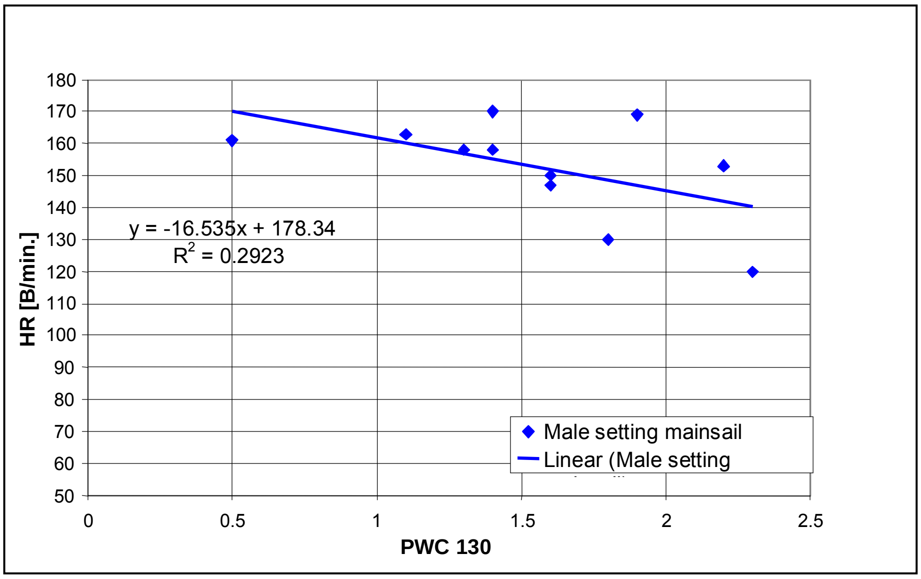

Fig.: 3-12: Heart rate as a function of fitness (PWC 130): setting the mainsail

- In the case of heavy mental load (e.g. “mooring under motor power”) the tendential link between heart rate and PWC 130 is:

  a higher (lower) level of PWC130 fitness of 0.5 points reduces (increases) heart rate by approximately 15 bpm.

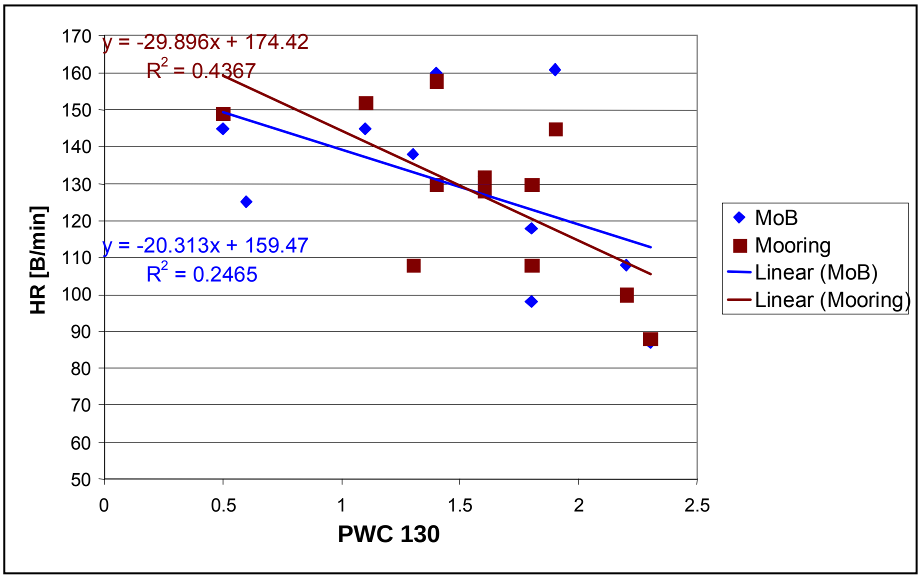

Fig.: 3-13: Heart rate as a function of fitness: man overboard, mooring under motor power

Notes:

- o The observations would suggest that cardiovascular fitness has a greater influence on sensitivity to stress than on physical performance.
- o A 0.5 point increase in PWC 130 fitness requires additional sporting activity on a scale of approximately five hours per week.
- o In terms of the heart rate coordinates for this age group, the gap between the load categories in accordance with the Borg scale (e.g. the gap between “tiring” and “very tiring”) is approximately 16 bpm.

8. The heart rate measured in the case of mental load tends to depend on the subject's specific level of experience. The stress-induced heart rate for both "mooring under motor power" and "man overboard" tended to be lower in more experienced test subjects (sea miles per year).

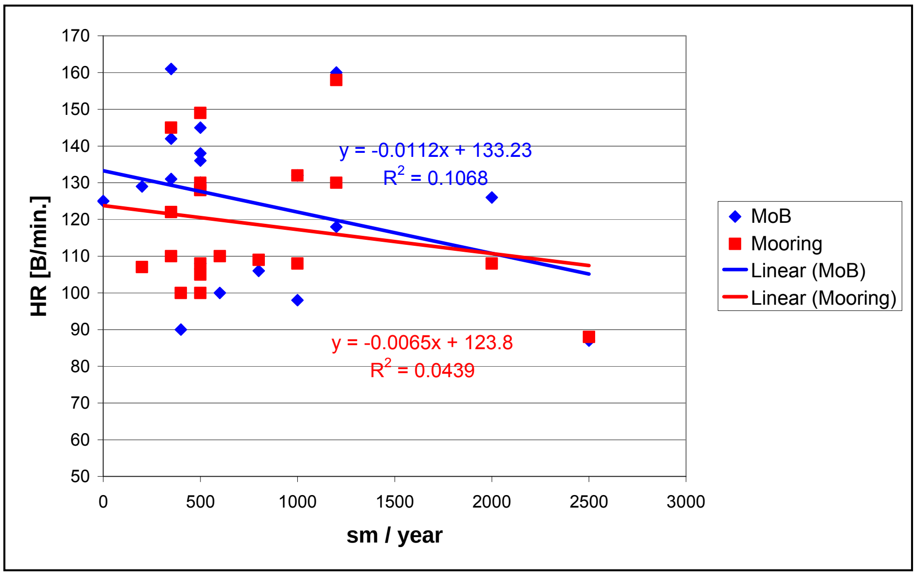

Fig.: 3-14: Heart rate as a function of experience/training (in sm/year): man overboard, mooring under motor power

9. Both the physical load generated by the relevant manoeuvres (e.g. setting the sails, hauling the sheets) and the mental loads experienced on board (e.g. mooring under motor power) increase significantly with rising wind force.
The following average increases in heart rate were observed during manoeuvres carried out at a rise in wind force from 3 to 4 Bft:
   - "Setting the main sail": + ca. 8 bpm.
   - "Turn at the sheet": + ca. 12 bpm.
   - "Mooring under motor power": + ca. 14 bpm.

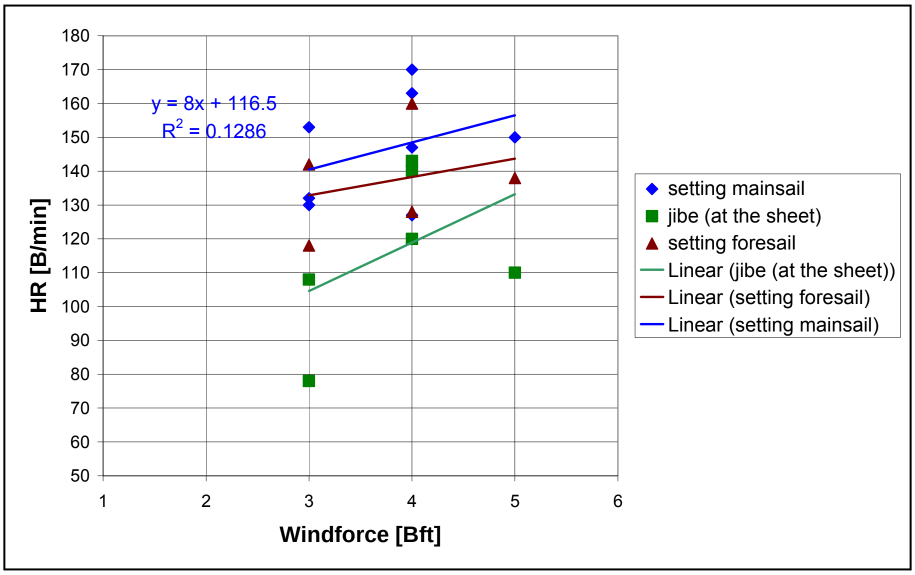

Fig.: 3-15: Heart rate as a function of wind force: with physical load

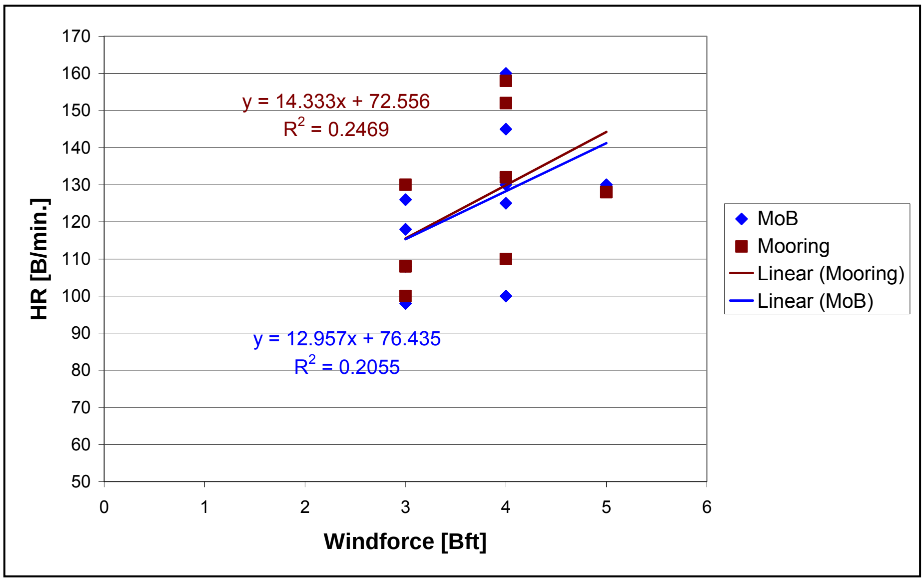

Fig.: 3-16: Heart rate as a function of wind force: with mental load

3.3 Age dependency

The fact that maximum individual heart rate declines with increasing age is an accepted fact.

The standard value used hitherto is calculated using the formula:

HR_{max} = 220 - age (men).

Recent longitudinal studies have produced the following gender-independent formula:

HR_{max} = 207 - 0.7 * age.

It is not possible to determine conclusively here whether this decline is – as hitherto assumed – 10 bpm per decade or – as suggested by more recent studies – only 7 bpm per decade.

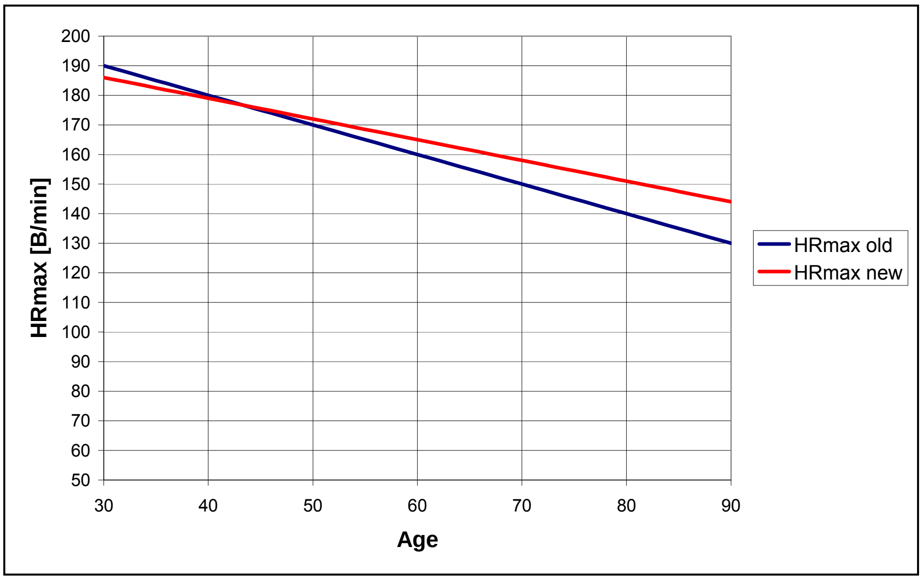

Fig.: 3-17: Old and new prognostic formulae for the age dependency of maximum heart rate

Of relevance in prognostic terms is the approach whereby with age-related declining maximum heart rate, the relative heart rate for defined loads increases and with this, in accordance with the Borg scale, the subjectively perceived exertion.

As already mentioned, the available tests confirmed that the measured heart rates for both physical and mental loads and taking individual and external influence factors into account are dependent on the nature of the load but largely independent of the age of the actors.

As a result for the areas of exertion studied, it may be concluded that a series of the typical activities on sailing yachts must be classified as “very tiring” with heart rates of over 130 bpm for the male age group “60+” and as reaching the upper performance limit for the “70+” age group.

This makes the assumption very likely that the subjective load involved in the handling of boats which increases with age – quantified as relative heart rate – is an important factor in the decision-making processes of elderly sailors concerning their retirement from active cruise sailing.

4 The “ComfoDrive” Subproject

In response to the observation that close-proximity manoeuvring with sailing yachts under motor power, in particular in the presence of disturbance variables (crosswind, current), can lead to high stress loads and serious safety problems, a technical solution was developed and tested as a prototype which guarantees the control of the boat on the water with the help of lateral thrusters.

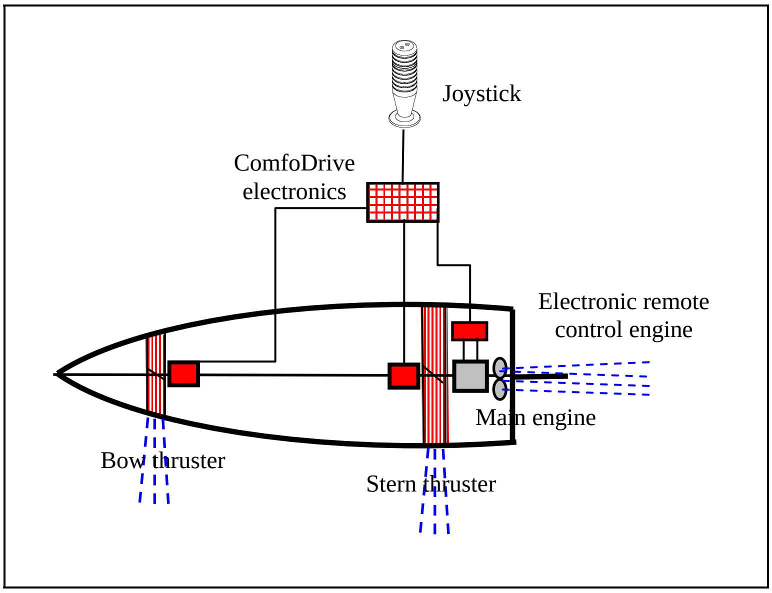

Fig.: 4-1: The ComfoDrive concept

Part of this solution involves a joystick concept with which all of the boat’s motorised drives are combined in a vectorising control unit and are steered orthogonally (forward-backwards/sideways/turning) using a special three-axis joystick.

The results of the two-year technical and ergonomic tests of prototypes of the ComfoDrive system revealed a significant improvement in manoeuvring safety, a major reduction in the stress load of the helmsman and impressive technical stability of the system.

The concept was registered as a patent.

It is planned to develop complementary "assistance systems" in follow-up projects that build on the ComfoDrive's orthogonal interface. These include, inter alia, a "TrackAssistant" for "electronic anchoring", "tracked manoeuvring" and "electronic mooring" based on a decimetre-precise sensor system for geo-positioning.

5 Open Questions

The perceptible changes in the capacity for action on board with increasing age concern not only physical fitness, but also, *inter alia*, mobility and coordination as well as emotional and psychological capacities.

This sports medicine study concentrates on individual types of loads experienced "on deck" and their quantification with the help of heart rate measurements.

In terms of the documentation of the wide-ranging problems that can arise on board, which are omitted here, important issues are described in a special section of the full version of the project report and commented on – where possible – with references to possible solutions.

The lack of age- and gender-related comparative and standard data for the different load and mobility situations that arise on board, emerged as an important deficit in the information currently available.

In view of this, the FVSF, in cooperation with the ISS at the University of Kiel and the Center of Maritime Technologies (CMT), submitted a project application to the German Federation of Industrial Research Associations (AiF) in early 2009, funding for which was authorised in July 2009. The aim of the project is to develop a systematic catalogue of standard data for use in the construction of boats within a period of 2.5 years from early 2010.

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7 Disclaimer and Contact Information

To err is human, therefore the following should be noted.

The data and information contained in this report were collected, analysed and evaluated with extreme care. However, it is still possible that errors were made in the research, interpretation and writing.

The authors assume complete responsibility for the content of this study but must reject all liability claims arising from damage that may arise from the use of the information in this report.

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