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The Six-Minute Walk Test on the Treadmill

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1. Introduction

Human physical efficiency is shaped by several factors amongst which the functional condition of the heart, lungs and arterial circulation in lower limbs are regarded to be of key importance. Several tests are applied to evaluate human physical efficiency, however, the six-minute walk test (6MWT) deserves special attention due to its usefulness and simplicity. The test builds on the patient's walking capacity, i.e. the natural physical activity. Hence, the performance of the test does not require any individual preparation. The only and at the same time simple evaluation factor in the test is the distance covered within 6 minutes on a flat area. During the six minutes, the patient adjusts the pace of the walk to his or her fatigue, dyspnoea or pain in the lower limbs. According to the recommendations formulated by the American Thoracic Association in 2002, the test should be performed in subjects with at least moderate heart failure, respiratory failure or arterial circulatory failure in lower limbs.

The six-minute walk test is used by physicians as it enables the impartial evaluation of physical efficiency and treatment effectiveness. It also plays a prognostic role in evaluating the life span of patients with heart failure. It is easy to perform the test in a hallway. However, it is difficult to compare the results of the tests in various medical centres because they are performed in hallways which differ in length. In order to overcome this limitation, ATS 2002 guidelines state that the standard length of the hallway should be 30 m and its standard width – 3 m. The hallways in some medical centres comply with the set standards for the 6-minute walk test. However, even in these centres the test cannot be performed because the hallway has been designed for internal circulation purposes. Since several centres do not have a hallway with the required length, the six-minute walk test is performed in halls of non-standard length. Hence, a situation occurs when the right ATS guidelines cannot be complied with for technical reasons.

The idea to circumvent the limitation resulting from various hallway lengths was brought up during a visit to a cardiac rehabilitation centre with very well equipped physical efficiency laboratories in which the patient performing the six-minute walk test disappeared behind the hallway corner changing the direction at a right angle. This rather bizarre situation gave rise to the idea of doing the six-minute walk test in optimal conditions, i.e. in a physical efficiency laboratory, on the treadmills used there. After all, it is enough to adapt the speed of the

treadmill belt to the pace of the patient's walk by means of the appropriate program and sensors. In this way, a situation equivalent to a hallway walk will be reconstructed where the patient slows down or even stops if tired. The team of constructors from ITAM (Institute of Medical Technology and Equipment) in Zabrze started research into this idea. As a result of their work, a treadmill was constructed which adapts to the walking capacity of a patient suffering from chronic obstructive pulmonary disease (COPD), heart failure (HF) or arterial circulation failure in lower limbs. The algorithm designed to control the speed of the treadmill belt is based on precise, wireless determination of the patient's position on the belt.

The second part of the chapter demonstrates the results of the engineers' work on the construction of the treadmill in order to perform the walk test safely. The third part of the chapter contains the evaluation of adjustment of the treadmill to the walking pace of healthy volunteers, as well as a comparison of the distance covered during the 6-minute walk on the treadmill and in the hallway.

The obtained results demonstrating the advantages of the treadmill, have encouraged us to perform a 6MWT for patients with heart failure in the II-III NYHA classes (unpublished trial). The treadmill test was tolerated equally well by the patients as the hallway test. The fact that a similar distance was covered in both tests demonstrates that the technological barrier preventing us from obtaining credible results of the six-minute walk test on the treadmill, has been overcome. Thus, the possibility of performing 6MWT on the treadmill for patients suffering from obstructive airways disease, heart failure, or intermittent claudication, has appeared.

2. The treadmill controlled by a patient's walk

The American Thoracic Society (ATS) in the report issued in 2002, appreciates the advantages of the 6MWT on a treadmill as it saves space and allows constant monitoring during the exercise (ATS, 2002). However, ATS has not approved the use of a treadmill to determine the six-minute walking distance (6MWD) because so far, patients have been unable to pace themselves on an ordinary treadmill.

The popularity of the 6MWT in clinical practice (Stevens et al., 1999; Montgomery & Gardnem, 1998; Roul et al., 1998; Zugck et al., 2000; Rostagno et al., 2003), problems with the performance of the test on the treadmill, as well as the differences between the 6MWT in the hallway and on the treadmill encouraged us to develop a treadmill which applies the algorithm of the safe speed adjustment to the walking capacity of the patient. The purpose of our work was to construct a treadmill which enables the patients to move at their own pace during the walk, as well as to check if such a treadmill would be sufficient to perform the 6MWT.

The paper describes the reasons and a series of works which have led to the development of a new treadmill type adapted to the performance of the 6MWT. The new treadmill, which allows the patients to walk at their own pace, could be useful in rehabilitation, evaluation of physical efficiency, sport training and recreation.

2.1 Preliminary works

The common treadmill forced patients to adjust their walking speed to its belt speed so as to prevent them from being pushed off the belt. The new treadmill changes its belt speed with

the patient's changing walking speed. It is done quickly enough to keep the patient still on the treadmill. At the beginning, the preparation of such a treadmill seemed difficult for us and a different solution was chosen. We decided to combine the speed of the belt with the patient's position on the treadmill. When the patient is close to the front of the treadmill, the maximum speed of the belt is achieved, when he is close to the end of treadmill, the belt stops. While increasing the walking speed, the patient moves toward the front of the treadmill and the belt speed increases, when he slows down, the belt moves him backwards and the belt speed adjusts again. In order to realize such an algorithm, precise measurements of the patient's position on the treadmill are necessary. Already at the beginning, a decision was made to measure the position wirelessly because all the other methods were rather inconvenient.

First of all, the use of the ultrasound wave, reflected by the patient on the treadmill, was chosen to measure the distance from the patient to the front of the treadmill. Due to parasitical echoes from the other objects around, measurements were uncertain and the method turned out to be inconvenient. Because transmitting and receiving ultrasonic waves is simple and cheap in practice, we decided to continue using ultrasound after some modification. In the new method, the patient was carrying a transmitter which produced simultaneously a short impulse of ultrasound wave and infrared beam (about 100 milliseconds long). Both signals were received by the receiver at the front of the treadmill and the distance between the transmitter and receiver was calculated from the time delay between the received signals. Distance measurements turned out to be accurate (error less than 10 mm) and due to the shortest direct way of the ultrasound signal, parasitical echoes did not interfere with the measurements.

Fig. 1 shows the idea of the patient's position measurement using a mixed ultrasound/infrared method. Carrying a transmitter seemed slightly uncomfortable for the patient, but

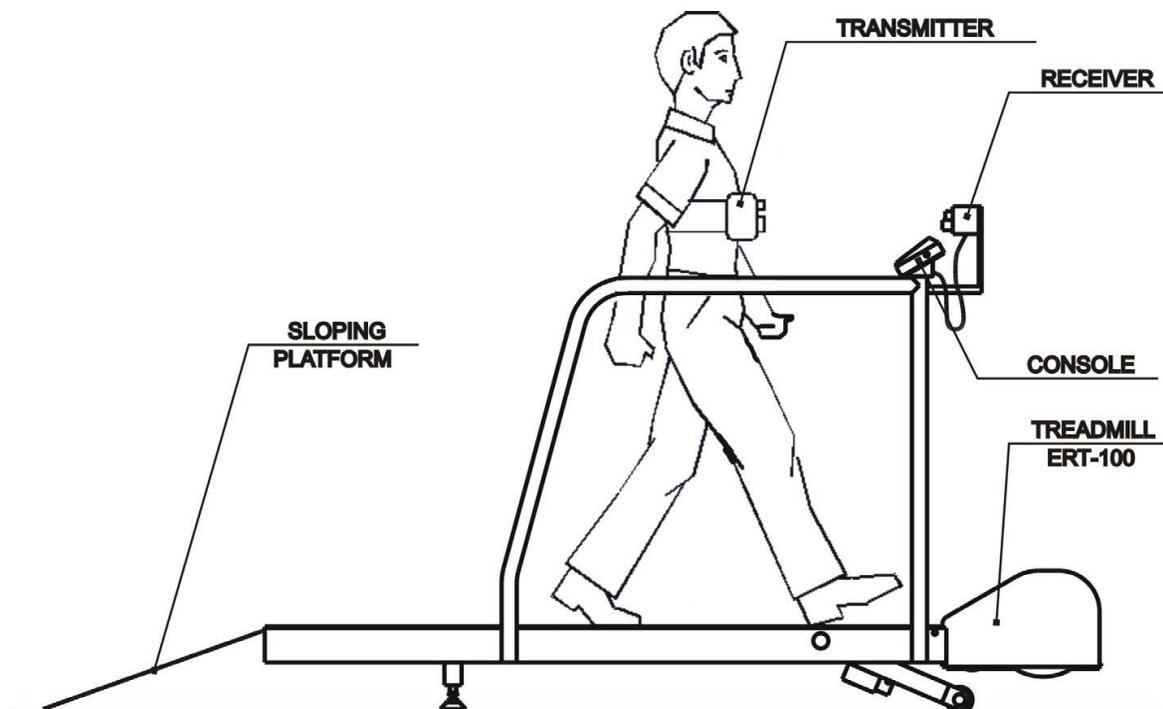


Fig. 1. Six-minute walk test on the treadmill

safe, because only the person carrying the transmitter could operate the treadmill. Additionally, an infrared beam was used to transmit the patient's heart rate (HR) displayed at the control panel of the treadmill.

As soon as the position measurement system with the transmitter and receiver was ready, we began to prepare the treadmill to control the speed. We adapted the treadmill ERT-100 constructed by ITAM, by connecting the receiver and introducing a new control program to its console. By using "the 6-minute walk test program" in the control panel, the operator could input the maximum speed of the treadmill belt and start the test. After 6 minutes from the start of the test program, the test came to an end and displayed the distance covered by the patient. The treadmill belt achieved its maximum speed when the distance between the receiver and transmitter was less than 30 cm and stopped when the distance was longer than 120 cm. Between those two distances, the speed was changing proportionately from 0 to the maximum value which could not exceed 10 km per hour. The ERT-100 treadmill, modified as described above, was examined by a group of 6 healthy volunteers, the employees of ITAM in Zabrze.

The volunteers carried out the 6MWT on the treadmill and in the hallway on two separate days, according to the protocol described in (Lipkin et al., 1986). Distances covered by the volunteers in both tests were similar and the participants found the treadmill test more comfortable than the hallway test. Although the results were satisfactory (Redelmeier et al., 1997), some drawbacks of the treadmill and control algorithm appeared:

- the treadmill ERT-100 was too short for such a control algorithm; an additional sloping platform was necessary for the patient's safety, the patient's rapid stop could be dangerous for him;
- the range of position change was narrow, which caused restless movement of the belt; at the same time, slight changes caused perceptible change of speed;
- the belt speed change ramp was too slow and the treadmill reacted too slowly to rapid changes of the patient's speed;
- the illusion of similarity to a hallway walk was partial, the patient always had to pay attention to maintaining the desired speed.

It was obvious that we could not change the treadmill to eliminate all of these disadvantages, so we had to prepare a new control algorithm instead.

2.2 Main results

A new idea of treadmill control is shown in Fig.2 as a block diagram. The distance measurement method has remained the same, however, the receiver has got some additional functions. As opposed to the former version, the console is used only for communication with the operator.

The treadmill control algorithm is realized by a microcontroller in the receiver, while the console transfers only the speed and slope signal to the treadmill.

The belt speed change ramp, previously programmed in the console, can now be changed as required for the test. We decided to return to the idea of a treadmill that changes its belt speed along with the patient's changing walking speed - one that does it quickly enough to keep the patient still on the treadmill. The microcontroller in the receiver maintains the

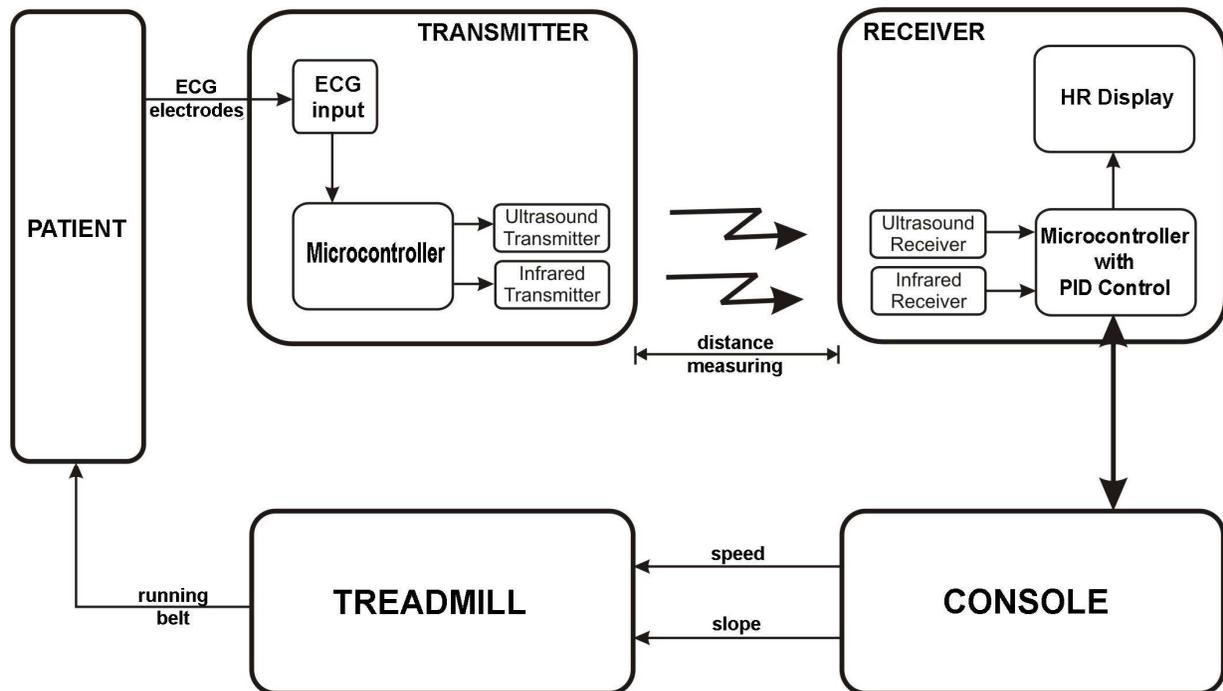


Fig. 2. Block diagram of a treadmill controlled by the patient's walk

patient's stable position on the treadmill regardless of the walking speed by means of a controller utilizing a PID algorithm (proportional - integral - derivative). The algorithm takes into consideration the maximum allowed belt speed set in the console by the operator and the maximum allowed distance from the receiver in which the belt stops. This distance lets the patient stop without a risk of falling off the treadmill. Fig. 3 shows a block diagram of the PID control algorithm.

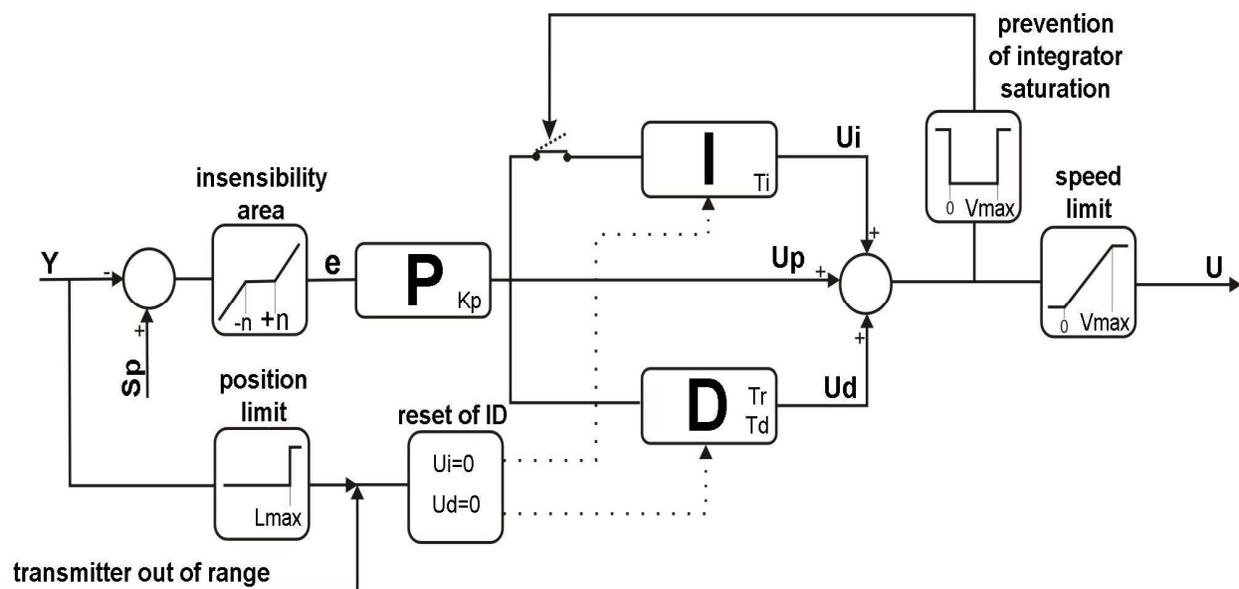


Fig. 3. PID controller algorithm

Several blocks have been added to the standard PID controller structure. First, the insensibility area block prevents the PID's operation when the difference between the

patient's position and the preset position is negligible. Second, the speed limit block prevents the patient from achieving belt speeds that could be dangerous. The limit is preset by the treadmill operator. Third, the position limit block stops the treadmill belt when the patient's position is outside the controlling range. The same happens if the transmitter signal is lost, e.g. when the transmitter is out of range or inoperative. Another block which prevents the integrator from saturation, stops integration when the belt speed is out of range. The last block resets the controller's integral and derivative blocks.

The above diagram uses the following symbols:

Y	-	the distance between the transmitter and receiver
S_p	-	the preset patient's position on the treadmill
U	-	the treadmill belt speed
E	-	error, difference between the preset position and current distance
K_p	-	the controller proportional gain
T_I	-	the controller integral time
T_r	-	the controller derivative time
T_d	-	the inertia time base

The equations which describe each part of the PID controller are as follows:

$$\begin{array}{ll}
 \text{P:} & U_p(s) = k_p \cdot e(s) \\
 \text{D:} & U_d(s) = U_p(s) + U_i(s) + U_d(s) \\
 \text{I:} & U_i(s) = k_p \cdot \frac{1}{s \cdot T_i} \cdot e(s) \\
 \text{U:} & U_d(s) = k_p \cdot \frac{s \cdot T_r}{1 + s \cdot T_d} \cdot e(s)
 \end{array}$$

The treadmill control using the PID controller described above has been simulated with the use of LabView software. The simulation enables us to specify rough parameters of the controller. Fig. 4 shows the LabView screen during a simulation of the treadmill belt speed control. A program for the PID controller was implemented, with constants specified during simulation, into the receiver's microcontroller and checked by volunteers walking on the treadmill at varying speeds. During the tests, the PID controller parameter was being tuned to achieve the best results.

The personnel performing the tests often had different subjective views on the best set of controller constants. Each person had his own favourite algorithm. The differences seemed to be negligible at the time, however, they will become more meaningful if there are differences between patients (due to age, incapacity, disability).

At the end of the test round, an additional test was carried out, using the treadmill's ability to change its elevation. During the 6MWT, after covering part of the route preset in the program, the treadmill changed its elevation in accordance with the value specified in the program. The test showed that elevation changes did not affect the performance of the test.

As a result, we have developed an algorithm that makes the 6-minute walk test on the treadmill much safer than at the beginning and very similar to a classic hallway test. It has allowed us to prepare a commercial version of the ERT-100 treadmill equipped with a transmitter and receiver. The treadmill has passed the CE certification procedure.

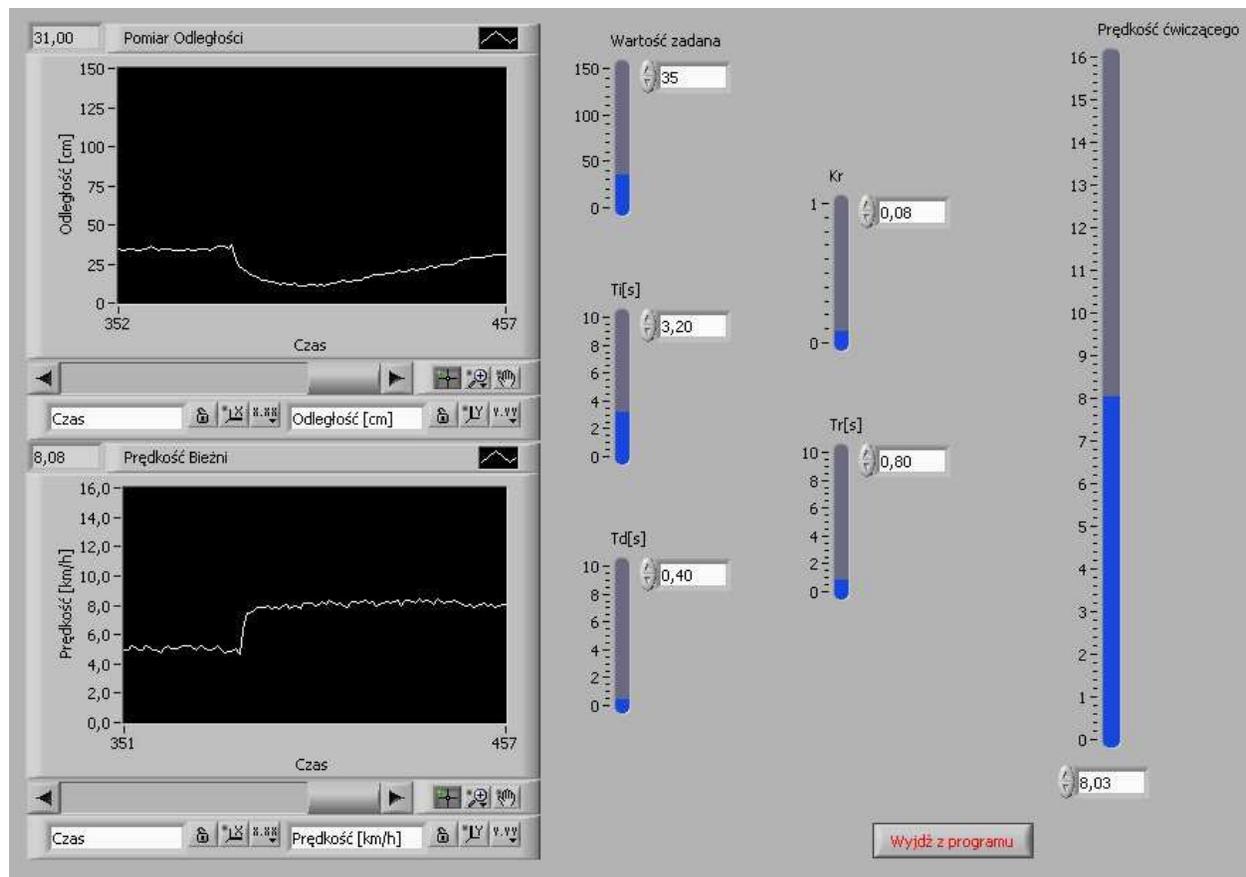


Fig. 4. LabView simulation of treadmill belt speed control

Probably the treadmills should be equipped with several algorithms, each of them focused on a different group of persons (elderly or young, fit or unfit). A treadmill with a CE certificate allows us to choose the best control algorithm for each group of people through research carried out on a large population.

The “6-minute walk test” is not the only application of the treadmill controlled by the patient’s walk. It is easy to imagine many other tests based on the same principle, for example a “2-kilometer walk test” where the principle of 6MWT is inverted and the time elapsed after covering the distance is the final result. By adding elevation changes of the treadmill to the walk, we obtain a system which simulates a cross country test, unknown in medicine but well known in sport training.

ITAM is currently working on a new family of treadmills with new features and enhanced characteristics (e.g. enhanced dimensions, higher speed). The new treadmills will be equipped with an algorithm which controls the belt speed not only while the patient is walking, but also while he is running. Position measurements are essential if the treadmill is controlled by the patient’s walk. Works are in progress on a new family of treadmills using other methods to determine the patient’s position. The achieved results seem to be the same or even more promising than before.

3. A six-minute walk test on a special treadmill: Primary results in healthy volunteers

The guidelines approved by the American Thoracic Society (ATS) in 2002 definitely recognize the six-minute walk test (6MWT) as a useful tool for the evaluation of physical efficiency in individuals with at least moderate chronic obstructive pulmonary disease, heart failure and intermittent dysbasia (ATS, 2002). In order to compare the results obtained in various research centres, the guidelines recommend that the test be performed in a hallway 30 m in length and at least 3 m in width. As a result, some centres without hallways of this area have a limited possibility of carrying out this simple test.

The authors of the ATS report appreciate the advantages of the 6MWT on a treadmill as it saves space and allows constant monitoring during the exercise.

So far, ATS has not approved the use of a treadmill to determine the six-minute walking distance (6MWD) because patients are unable to pace themselves on a treadmill. The divergence between the distances covered on the treadmill and in the hallway was pointed out. To support this point of view, a study of patients with severe lung disease was presented where the mean distance walked on the treadmill was shorter by 14% when compared with the standard 6MWD using a 30 m hallway (Stevens et al, 1999). In particular, doubts were expressed regarding the wide range of differences, with patients walking between 120÷390 m on the treadmill and 360 m in the hallway.

The popularity of the 6MWT in clinical practice (Montgomery & Gardnem, 1998; Roul et al., 1998; Zugck et al., 2000; Rostagno et al., 2003; Lipkin et al., 1986; Redelmeier et al., 1997), problems with the performance of the test on the treadmill and our first positive results with the use of a modified treadmill adapting to the pace of the patient's walk, encouraged us to check if our version of the algorithm enables healthy volunteers to cover a similar walking distance both on the treadmill and in the hallway.

3.1 Methods

3.1.1 The population tested

29 healthy volunteers, full-time and extramural students of the Academy of Physical Education in Katowice, took part in a test. The volunteers were 28 years old (21÷48) on average. The order of taking the 6MWT on the treadmill and in the hallway was established at random. The tests with the use of both methods were performed at a 7-day interval.

3.1.2 The 6MWT in the hallway

For each individual, the 6MWT was performed along a corridor 22 m in length, according to Lipkin protocol (Lipkin et al., 1986). The participants were told to walk the distance of 22 m back and forth, at their own speed, in such a way that they would cover the longest possible distance within 6 minutes. The volunteers were allowed to slow down or stop, but at the end of the test they were expected to have the impression that they could not walk any further within 6 minutes.

3.1.3 The 6MWT on the treadmill

The software adjusting the ERT-100 treadmill belt speed to the patient's walking speed in the range of 1÷10 km per hour was applied for the six-minute walk test. The treadmill was

in a horizontal position and the belt speed was controlled by constant measurement of the patient's position on the treadmill.

After 6 minutes from the start of the test, the program ended the test and displayed the distance covered by the patient.

The test on the treadmill was preceded by a training session lasting a few minutes on the day before the actual test. During the training session the participant learned how the treadmill worked and walked a distance of 100 meters at a changeable pace, as well as practiced stopping and restarting the walk.

The participants were informed about the treadmill test in an identical way as about the hallway test.

3.1.4 Analyzed parameters

The comfort of the test and the distance covered in metres were subject to evaluation in both cases. The evaluation scale for comfort included the question of which type of test was less problematic during performance or whether the comfort of both tests was so similar that the differences were negligent. The number of indications to a given type of test was calculated. The treadmill was also monitored from the point of view of smooth speed adjustment to the individual's sudden slowdown without affecting his or her balance.

The pulse and blood pressure were measured before and after each test in order to assess the hemodynamic impact of both 6MWT varieties.

3.1.5 Statistical analysis

The aim of the statistical analysis was to compare the values of the distance covered, obtained in both 6MWT varieties. Also the heart rate and blood pressure before and after the test were compared using the Student's test for matched pairs for independent trials.

Multidimensional statistical research was conducted, as well the T2 test was applied for vectors of the expected values for both varieties in order to verify whether the compared research leads to similar hemodynamic consequences.

3.2 Results

The comfort of the treadmill test was indicated as better by 18/29 of the participants, the hallway test was indicated as better by 4/29 of the participants and both tests were evaluated as identical in terms of comfort by 7/29 of the participants.

During the test, healthy volunteers were walking most frequently with the speed of 7 km/hour (4÷10). The average distance covered on the treadmill was 683.0 m and was usually 57.1 m longer on average than in the hallway (Table 1). This difference turned out to be statistically significant. The participants covered 29 laps on average during the hallway test (19÷36).

No considerable difference could be seen in the heart rate before the tests. Also, the resulting accelerated heart rate after both types of tests did not show any marked difference (Table 2), just like blood pressure (Table 2).

Way of performing the 6MWT	Mean distance [m]	SD	Difference between the means [m]	P
Hallway	625.9	94.6	57.1	< 0.009
Treadmill	683.0	65.2		

Table 1. The distance covered during the six-minute walk test on the treadmill and in the hallway

Way of performing the 6MWT	Before the test						After the test					
	Hallway		Treadmill		Difference between the means	P	Hallway		Treadmill		Difference between the means	P
	Mean value	SD	Mean value	SD			Mean value	SD	Mean value	SD		
Heart rate [bpm]	76.9	12.9	81.4	13.3	4.5	<0.19	96.8	19.5	103.2	22.5	6.4	<0.25
Systolic pressure [mm Hg]	125.9	13.4	123.0	12.5	-2.9	<0.4	134.2	16.2	135.8	18.5	1.6	<0.73
Diastolic pressure [mm Hg]	81.4	7.8	80.2	8.0	-1.2	<0.57	83.7	11.8	82.6	9.6	-0.9	<0.71

Table 2. The heart rate and blood pressure before and after the test performed on the treadmill and in the hallway

The Hotteling T2 test was used to assess the equality of vectors of the expected values for seven analyzed parameters of the 6MWT.

The obtained result: $T_2=11.7$ and $F=7.3 \ll 53$ (where 53 stands for the threshold of the hypothesis at significance level <0.05) gives a clear evidence about the identical hemodynamic effects of both testing methods.

3.3 Discussion

The literature on the 6MWT does not provide any comparative material for our results obtained during a walk along a hallway 22 m in length performed by healthy individuals, 28 years of age on average. The mean distance covered by our volunteers amounting to 625.9 m may only be compared with the distance obtained by other researchers, walked by healthy subjects over 40 years of age. In the work by Enright et al. [11], the distance was equal to an average of 535 m, while in the work by Troosters (Troosters et al., 1999) - to 631 m. In comparison with the distance covered by the subjects in the study by Enright & Sherill (Enright & Sherill, 1998), our volunteers covered almost 100 m more. The recorded difference is very likely to be related to our volunteers' young age (29 on average). In the study by Troosters et al., the average distance in a 50-metre-long hallway was a few meters longer than that covered by our healthy volunteers who were two decades younger. Almost identical distances in completely different age groups may only be explained by the fact that older patients had to do two times fewer turnarounds in a 50-metre-long hallway.

ATS guidelines approved in 2002, which specify the length and width of the hallway, will certainly make it possible to compare the 6MWT results obtained in various centres. Another way of comparing the results obtained in various places is the proposed return to the idea of using the treadmill.

In our study most, i.e. 86% of the healthy volunteers who had participated in the test, evaluated the comfort of a treadmill test as better than or the same as the hallway test. Hence, the applied design solutions and algorithm may be regarded as appropriate and flexible in terms of adjusting the speed of the treadmill belt to the walking speed of a healthy individual.

In the paper by Stevens et al., the participants could put in motion, speed up and slow down the treadmill by means of a special switch (Stevens et al., 1999). Although Stevens et al. enabled the participants to adjust the treadmill to their walking speed "by hand", the distance covered on the treadmill turned out to be shorter indeed than the distance walked in the hallway because the participant could hardly adjust to the speed of the treadmill belt.

We applied a treadmill which adjusts its speed to the walking capacity of the individual. As a result, the persons taking part in the test covered a distance 57.1 meters longer on average than in the hallway. The distance covered on the treadmill is longer than that walked in the hallway both due to flexible adjustment of the treadmill belt to the walking speed and due to avoiding multiple turnarounds and hence the need to speed up and slow down in the hallway test.

The multi-aspect analysis of the results including the distance covered, blood pressure and pulse measured before and after the 6MWT, shows similar hemodynamic consequences for both methods. Thus, it can be inferred that in the future it will be possible to determine the conversion rate, at least for healthy subjects, facilitating the comparison of the results obtained during a test in a 30-m hallway with the results on an adjustable treadmill.

As opposed to conditions in the hallway, the 6MWT on a moving treadmill creates possibilities of easy monitoring of heart rate and arterial blood pressure. This enables the hemodynamic surveillance that is necessary for the safe test performance in patients with cardiac insufficiency.

The attempt by Stevens et al. to use the treadmill for a 6MWT in patients with respiratory failure did not meet the expectations as it shortened the distance in comparison with a hallway test. Our results show the expected elongation of the distance compared with the hallway test, although they cannot be currently referred to patients with intermittent dysbasia, heart failure or severe lung disease. Patients suffering from such diseases are less fit, which may affect their ability to perform the 6MWT on a modified adjustable treadmill. We are aware of the fact that the decision whether our modified treadmill meets the expectations of physicians who use the 6MWT in their medical practice and research can only be made after performing the tests in these groups of patients. In finished, but yet not published trial we assumed that the quality of the algorithm version adjusting the speed of the treadmill belt to the pace of the patient's walk during the six-minute walk test (6MWT) on a moving treadmill, checked for healthy volunteers, makes it possible to perform the test safely in patients with heart failure (Szczurek et al., 2006; Prochaczek et al., 2007).

The work was intended to compare the distance covered, the level of exertion and hemodynamic effects in a hallway test and in a test on a modified treadmill for patients with

heart failure in NYHA functional class II-III. Twenty people with diagnosed heart failure and tolerance of physical exercise in NYHA functional class II-III took part in the tests.

The analysis of the performance and results of the test indicates that during the six-minute walk test on a modified treadmill, HF patients in NYHA class II-III may slow the treadmill down safely or stop, depending on their exertion level. Our research has demonstrated that a walk test performed on a treadmill, controlled by means of the pace of the patient's walk, is equally well tolerated and generates exertion (Borg Scale $11,87 \pm 2,90$) that is similar as in case of the classic hallway test (Borg Scale $11,87 \pm 2,90$).

The fact that we have proved that there are no statistical differences in the distance covered (treadmill $317,36 \pm 133,92$, hallway $312,43 \pm 117,76$) and in the hemodynamic effects of the test performed on a treadmill compared to a hallway test, enables us to use a modified treadmill to replace the hallway test and vice versa, in order to evaluate patients with HF or chronic obstructive pulmonary disease. The fact that a similar distance was covered in both tests demonstrates that the technological barrier preventing us from obtaining credible results of the six-minute walk test on the treadmill, has been overcome. The availability of a treadmill adapting its pace to the patient's capacity, makes it possible to start treatment assessment or rehabilitation in patients with HF or COPD both inside and outside the hospital. If the results of our work are confirmed by other authors, the centres specializing in exercise tests will certainly be able to perform six-minute walk tests, while the hallways in hospitals and medical centres will be used for internal circulation purposes, as designed.

The modified treadmill providing solutions that are not offered by any other companies, may be additionally recommended for fitness purposes because the person using the treadmill may avoid dyspnoea by adjusting his or her walking speed.

4. Conclusions

The paper describes reasons and a series of works which have led to the development of a new treadmill type adapted to the performance of the 6MWT in patient with heart failure, chronic obstructive pulmonary disease or arterial circulation failure in lower limbs.

The common treadmill forces patients to adjust their walking speed to its belt speed. The new treadmill changes its belt speed while the patient changes walking speed. The preparation of such a treadmill needed to combine the speed of the belt with the patient's position on the treadmill. While the patient increasing the walking speed, the patient moves toward the front of the treadmill and the belt speed increases, when he slows down, the belt moves him backwards and the belt speed adjusts again. In order to realize such an algorithm, precise measurements of the patient's position on the treadmill are necessary. The idea of the patient's position measurement was based on using a mixed ultrasound/infrared method.

According to the new method, the patient was carrying a transmitter which produced simultaneously a short impulse of ultrasound wave and infrared beam (about 100 milliseconds long). Both signals were received by the receiver at the front of the treadmill and the distance between the transmitter and receiver was calculated from the time delay between the received signals. Distance measurements turned out to be accurate (error less than 10 mm) and due to the shortest direct way of the ultrasound signal, parasitical echoes

did not interfere with the measurements. As a result, we have developed an algorithm that makes the 6-minute walk test on the treadmill much safer than at the beginning and very similar to a classic hallway test. It has allowed us to prepare a commercial version of the ERT-100 treadmill equipped with a transmitter and receiver. The treadmill has passed the CE certification procedure.

The second part of the chapter contains the evaluation of adjustment of the new treadmill to the walking pace of healthy volunteers, as well as a comparison of the distance covered during the 6-minute walk on the treadmill and in the hallway. A better comfort of the 6MWT and a longer distance covered on the treadmill compared with the distance covered in the hallway may indicate that the algorithm of adjusting the speed of the treadmill to the walking capacity of the tested individual has been properly selected.

The obtained results demonstrating the advantages of the treadmill in healthy volunteers have encouraged us to perform a 6MWT for patients with heart failure in the II-III NYHA classes. In yet not published material it has been shown that the treadmill test was tolerated equally well by the patients as the hallway test. The fact that a similar distance was covered in both tests demonstrates that the technological barrier preventing us from obtaining credible results of the six-minute walk test on the treadmill, has been overcome.

The availability of a treadmill adapting its pace to the patient's capacity, makes it possible to start treatment assessment or rehabilitation in patients with HF or COPD both inside and outside the hospital.

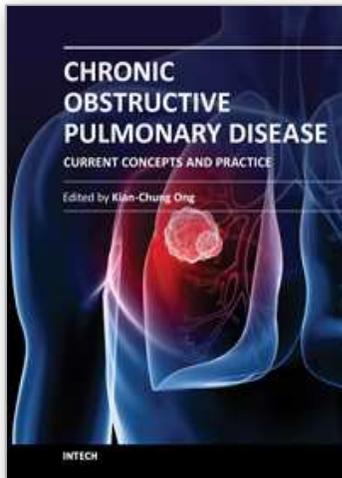
5. Acknowledgements

The authors would like to thank all the volunteers from the Academy of Physical Education in Katowice for their participation in the tests.

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Chronic Obstructive Pulmonary Disease - Current Concepts and Practice

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A decade or so ago, many clinicians were described as having an unnecessarily 'nihilistic' view of COPD. This has certainly changed over the years... This open access book on COPD provides a platform for scientists and clinicians from around the world to present their knowledge of the disease and up-to-date scientific findings, and avails the reader to a multitude of topics: from recent discoveries in the basic sciences to state-of-the-art interventions on COPD. Management of patients with COPD challenges the whole gamut of Respiratory Medicine - necessarily pushing frontiers in pulmonary function (and exercise) testing, radiologic imaging, pharmaceuticals, chest physiotherapy, intensive care with respiratory therapy, bronchology and thoracic surgery. In addition, multi-disciplinary inputs from other specialty fields such as cardiology, neuro-psychiatry, geriatric medicine and palliative care are often necessary for the comprehensive management of COPD. The recent progress and a multi-disciplinary approach in dealing with COPD certainly bode well for the future. Nonetheless, the final goal and ultimate outcome is in improving the health status and survival of patients with COPD.

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