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Hemodynamic differences in isometric counter-pressure maneuvers and their efficacy in vasovagal syncope

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Abstract

Background: Isometric counter-pressure maneuvers (ICM) were proposed as first-line treatment in patients with vasovagal syncope (VVS). The aim was to study hemodynamic mechanisms and effectiveness of ICM in prevention of head-up tilt (HUT)-induced and spontaneous VVS.

Methods: In 38 patients with VVS (9 men, 28 women, mean age 35.82 ± 15.2 years), following ICM were performed—squatting (SQ), leg crossing with muscle tensing (LCMT), whole-body tensing (WBT), heel raises (HeR), toe extension (TE), and unilateral handgrip (HG). Hemodynamic parameters were recorded during ICM using photopletysmographic principle: blood pressure, heart rate, cardiac output, stroke volume, and total peripheral resistance. Clinical efficacy of ICM was assessed during HUT-induced presyncope. The recurrence of syncope and quality of life were also evaluated during 26 ± 7 month follow-up period.

Results: All maneuvers increased mean arterial pressure. The hemodynamic background of ICM was not uniform. In most ICM (LCMT, WBT, HeR, and TE), an increase in CO due to simultaneous increase in HR and SV was observed. In SQ, the underlying mechanism was augmentation of stroke volume by increased venous return. In unilateral HG, a rise in peripheral resistance was the principal mechanism. ICM were able to prevent syncope in 47% of patients during HUT-induced presyncope and in 71% of patients during spontaneous presyncope. Quality of life improved in all patients.

Conclusions: ICM increase blood pressure by variable hemodynamic mechanisms. ICM effectively counteract the HUT-induced and spontaneous vasovagal syncope and improve quality of life.

Keywords: Isometric counter-pressure maneuvers, Hemodynamics, Head-up tilt test, Vasovagal syncope, Treatment

Introduction

Different treatment options have been proposed in the prevention of vasovagal syncope recurrences. Physical countermeasures have been suggested as a first-line treatment, especially in young patients with recognizable prodromal syndromes [1]. A different maneuvers were proposed—positional changes (lying down, bending forward, squatting, crash position, and leg crossing), dynamic muscle pumping (tiptoeing and walking), and isometric muscle tensing (arm tensing, leg tensing, isometric handgrip, and whole-body tensing) [2]. A number of small studies [3–7] and one large multicenter study [1] showed their efficacy.

Isometric counter-pressure maneuvers (ICM) are based on the fact that isometric muscle contraction increases blood pressure. ICM are recommended by current guidelines for patients with recurrent vasovagal syncope because of its efficacy and simplicity [8]. They are efficient also in patients with orthostatic hypotension [9] and improve orthostatic tolerance even in healthy persons [10]. In comparison to positional changes or dynamic muscle exercise, they draw less attention to affected persons suffering from presyncope what may be preferred in some situations.

From published literature, it seems that some of maneuvers are more efficacious than other. The efficacy

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of ICM is depending on the muscular mass involved. In general, maneuvers involving large muscle groups (whole-body tensing and leg muscle tensing) should be more efficient than maneuvers involving only smaller muscle groups (handgrip and arm tensing). Published data regarding the efficacy of isometric handgrip are controversial [4, 11, 12].

The aim of the present work was to study hemodynamic impact of different isometric counter-pressure maneuvers (ICM) in patients with recurrent vasovagal syncope and to assess their clinical efficacy.

Methods

155 patients with recurrent syncope underwent head-up tilt test (HUT). HUT was positive in 80 patients. From these 80 patients, 38 patients were included into study (9 men, 28 women, and mean age 35.82 ± 15.2 years). Mean number of syncopal episodes was 2.4 ± 1.6 (median 3). Inclusion criteria were recurrent syncope, absence of structural heart disease, positive HUT, presence of prodromal symptoms, physical and mental ability to perform ICM, and informed consent to participate in the study. All persons gave their informed consent to participate. Study was performed in accordance with declaration of Helsinki and was approved by Ethics committee VUSCH.

Exclusion criteria were: absence of prodromal symptoms, bradycardic and hypotensive drugs, and drugs and diseases influencing the autonomic nervous system activity.

All patients underwent complete clinical assessment and 12-lead electrocardiogram. Clinical history suggested the diagnosis of vasovagal syncope. The vasovagal etiology of syncope was confirmed by head-up tilt test (HUT), which was performed according to Italian protocol (20 min of passive standing in 60° position followed by 15 min of nitroglycerine stimulated test).

Isometric counter-pressure maneuvers

Following maneuvers were performed in all patients.

1. Squatting (SQ): position with posterior surfaces of calves pressed against posterior sites of thighs, the trunk is tilted forward, and hands are positioned on the floor.
2. Leg crossing with muscle tensing (LCMT): crossing the lower extremities simultaneously with tensing of leg muscles, buttock, and abdominal muscles for maximal tolerated time.
3. Whole-body tensing (WBT): tensing of all large muscles groups, namely lower a upper extremities, abdominal, neck, and dorsal muscles.
4. Toe extension (TE): dorsal flection in metacarpophalangeal joints of lower extremities resulting in isometric contraction of calf muscles and anterior thigh muscles.
5. Heel raises (HeR): standing on the tips of both feet leading to isometric contraction of calf muscles.
6. Unilateral handgrip (HG): flection of all fingers of dominant hand forming a fist leading to isometric contraction of upper extremity muscles.

Hemodynamic data acquisition

Blood pressure and other hemodynamic parameters were measured using a non-invasive continuous blood pressure monitoring system based on photopletysmographic principle (Finometer Pro, Finapress Medical Systems, The Netherlands). Following hemodynamic parameter were obtained from finger blood pressure curve using a Beatscope 1.1 software: systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP), heart rate (HR), cardiac output (CO), SV (stroke volume), and total peripheral resistance (TPR).

SV was calculated with the use of Modelflow method (Beat Scope, Finapress Medical Systems, Netherlands). CO was calculated as SV times HR. TPR was calculated from CO and MAP.

All measurements were done in last 30 s before ICM and in first 30 s during ICM. Arithmetic means from all beat-to-beat data were calculated in both intervals and used for further analysis.

Biofeedback learning of ICM

All above described ICM were performed in standing position. Most effective maneuver was selected. This was LCMT in 22 patients, WBT in 7 patients, and HeR in 1 patient. After selecting the most effective maneuver, patient was asked to repeat the selected maneuver several times to practice it. Biofeedback principle was used for teaching the maneuver. Blood pressure curve was displayed on the screen. Patient was able to see direct influence of his muscle contraction on blood pressure and to adjust the contraction to get optimal blood pressure response.

Patients were instructed to practice the selected maneuver at least once a day for period for 3 months to be able to perform it in optimal way, if syncopal prodromes occur.

ICM during HUT

In 33 patients (9 men, 24 women, and mean age 34.3 ± 14.5 years), control HUT was performed after 3 months of home ICM training. Five patients declined to participate on repeat HUT.

The same protocol was used as in first (diagnostic) HUT. If presyncope occurred during HUT, patients were asked to use the selected ICM (LCMT in 22 patients, WBT in 7 patients, and HeR in 1 patient) to abort syncope or prolong presyncope.

The ICM was interrupted and the patient was tilted back if one of the following situations occurred: (1) the loss of consciousness was inevitable, (2) presyncopal symptoms persisted despite ICM, or (3) presyncopal symptoms disappeared during ICM.

During control HUT, hemodynamic data were collected in the same way as in the training phase of the study.

Quality of life (QOL)

QOL was assessed after 3 months of home ICM training at the time of control HUT in 33 patients (9 men, mean age 34.3 ± 14.5 years). QOL was measured by the general health-related QOL questionnaire SF-36 and disease-specific questionnaire for assessing QOL in patients with syncope (SFSQ—Syncope Functional Status Questionnaire).

QOL was measured by F-36 in eight summary scores: physical functioning, social functioning, role limitation due to physical health, role limitation due to emotional problems, vitality, bodily pain, mental health, and general health perception. In addition, two composite scores were evaluated: physical component summary (PCS) and mental component summary (MCS).

SFSQ consists of 11 yes/no questions to assess syncope interference with patients' life and 3 Likert-scale questions assessing fear and worry related to syncope [13]. Following SFSQ scores were evaluated: impairment score (IS), fear/worry score (FWS), control score (CS), hope score (HS), and syncope dysfunction score (SDS).

Follow-up

In 38 patients, follow-up was performed. They were regularly contacted by telephone. Patients were asked to report the number of presyncopal attacks, the use of ICM during presyncope, and efficacy of ICM in aborting syncope.

Statistical analysis

Statistical analysis was performed using Student's *t* test and analysis of variance (ANOVA with Bonferroni comparison. All data were normally distributed. Statistical significance $p < 0.05$ was considered significant.

Results

All maneuvers significantly increased SBP and DBP ($p < 0.001$) (Figs. 1 and 2). Greatest increase in SBP was observed in LCMT (125.6 ± 20.8 mmHg vs. 149.2 ± 23.4 mmHg; $p < 0.001$). Greatest increase in DBP was observed also in LCMT (82.0 ± 16.0 mmHg vs. 92.3 ± 18.5 mmHg; $p < 0.001$).

Difference in mean SBP before and after maneuver was higher in LCMT than in SQ (23.6 ± 10 vs. 14.5 ± 12.2, $p < 0.001$), TE (23.6 ± 10 vs. 15.6 ± 9.4, $p < 0.001$), and HG (23.6 ± 10 vs. 13.9 ± 9.2, $p < 0.001$). All other differences were not significant.

Perfusion of the brain is mainly related to the mean arterial pressure (MAP). MAP increased significantly in all maneuvers, but the magnitude of this increase was different. Increase in MAP was highest in LCMT, WBT, and HeR. This increase was significantly higher in LCMT than in TE, HG, and SQ ($p < 0.001$). Smallest increase in MAP was present in SQ (Table 1).

Peak value of MAP during ICM was reached within 12 s in all patients. Fastest increase in MAP was noted in SQ and peak value was reached in 3.6 ± 1.3 s ($p < 0.001$ when compared to all other ICM). Slowest increase in MAP was present in HG (7.8 ± 3.5 s), ($p < 0.001$ when compared to all other ICM) (Table 2).

Hemodynamic measurements during ICM are shown in Table 1. Cardiac output (CO) increased significantly in all ICM except for HG. CO did not change in HG. In all other ICM, CO rose due to increase in SV and HR.

Most prominent increase in stroke volume (SV) was present in SQ. This rise was significantly higher when compared to all other ICM ($p < 0.001$). No rise in SV was present in HG.

HR rose significantly in all ICM except for SQ, where significant decline in HR was present ($p < 0.001$).

No significant changes in TPR were observed during LCMT, WBT, HR, and TE. During SQ, there was significant decline in TPR ($p = 0.012$). During HG, there was significant increase in TPR ($p = 0.002$).

Based on underlying hemodynamic mechanisms three different hemodynamic patterns responsible for the rise in blood pressure can be distinguished (Fig. 3):

Pattern 1: Increase in CO due to simultaneous increase in HR and SV. TPR does not change. This type of hemodynamic response was most frequent, and was noted in LCMT, WBT, HeR, and TE. Principal mechanism is the rise in sympathetic activity due to activation of mechano- and

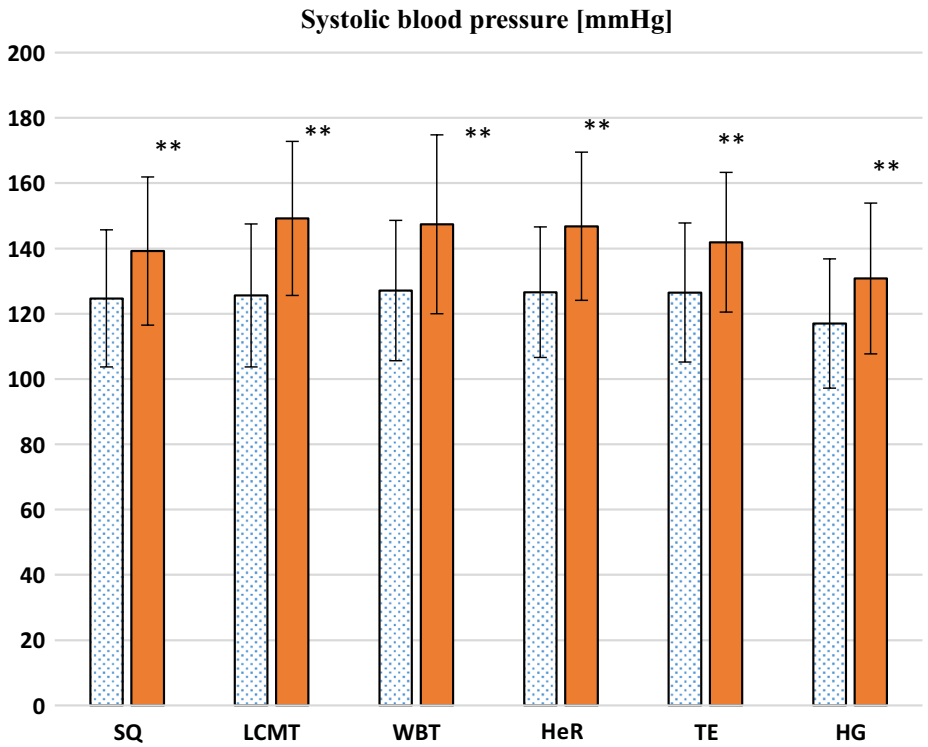

Fig. 1 Increase in systolic blood pressure during ICM. $^{**}p < 0.001$, *SQ* squatting, *LCMT* leg crossing and muscle tensing, *WBT* whole-body tensing, *He* heel raising, *TE* toe extension, *HG* handgrip

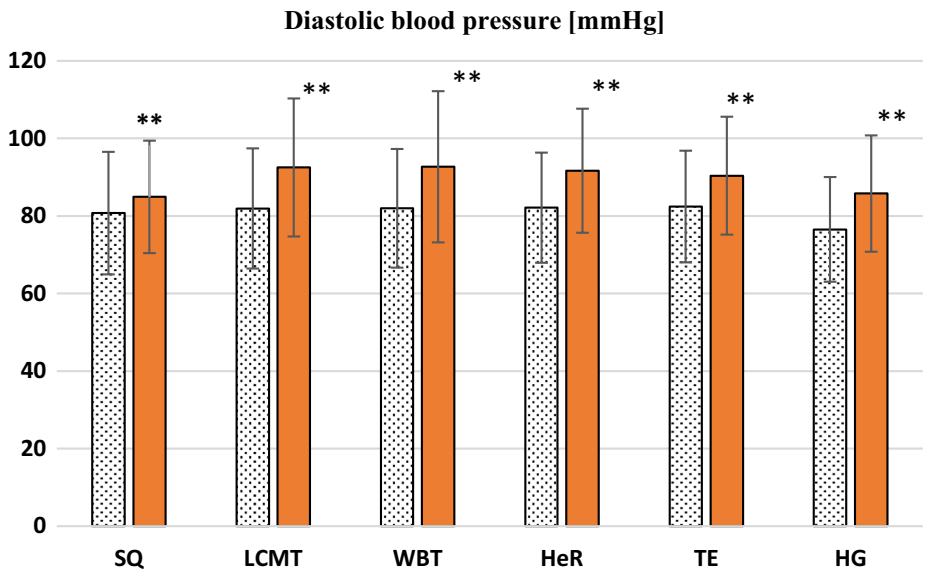

Fig. 2 Increase in diastolic blood pressure during ICM. $^{**}p < 0.001$, *SQ* squatting, *LCMT* leg crossing and muscle tensing, *WBT* whole-body tensing, *He* heel raising, *TE* toe extension, *HG* handgrip

Table 1 Hemodynamic parameters during ICM

	Before ICM	During ICM	Significance (*p*)	Difference
Mean arterial pressure (mmHg)				
SQ	98 ± 17.6	107.3 ± 17.4	< 0.001	9.4 ± 8.3
LCMT	98.3 ± 17.3	114.8 ± 19.3	< 0.001	16.6 ± 7.9
WBT	99.5 ± 17.4	114.4 ± 22.8	< 0.001	14.9 ± 10.5
HeR	99.6 ± 16.1	113.7 ± 18.3	< 0.001	14.1 ± 6.5
TE	99.6 ± 16.6	110.8 ± 17.1	< 0.001	10.9 ± 6.8
HG	98.7 ± 14.9	111 ± 16.8	<0.001	12.3 ± 7.3
Cardiac output (l/min)				
SQ	4.7 ± 1.7	5.7 ± 2	< 0.001	1 ± 0.8
LCMT	4.6 ± 1.6	5.6 ± 2.1	< 0.001	1 ± 0.8
WBT	4.8 ± 1.8	5.3 ± 2.1	< 0.001	0.5 ± 0.6
HeR	4.6 ± 1.7	5.4 ± 2.1	< 0.001	0.8 ± 0.7
TE	4.6 ± 1.6	5.3 ± 2.1	< 0.001	0.7 ± 0.7
HG	5 ± 1.5	5.1 ± 1.6	0.134	0.1 ± 0.4
Stroke volume (ml)				
SQ	51 ± 19.4	67.6 ± 21.6	< 0.001	16.6 ± 9
LCMT	50.9 ± 18.3	60.6 ± 23.3	< 0.001	9.7 ± 9.7
WBT	52 ± 19.3	55.9 ± 23.1	0.003	3.9 ± 7.3
HeR	50.6 ± 19.5	57.5 ± 22	< 0.001	6.9 ± 7.1
TE	49.6 ± 17.4	54.2 ± 19.7	0.001	4.6 ± 7.3
HG	52.5 ± 17.2	52.5 ± 16.1	0.940	0.1 ± 4
Heart rate (beats/min)				
SQ	92.4 ± 14.4	85 ± 10.5	< 0.001	− 7.4 ± 10.1
LCMT	93 ± 15	96 ± 16	0.031	3.0 ± 8.3
WBT	94 ± 16.6	98.8 ± 18.7	0.005	4.7 ± 9.6
HeR	91.9 ± 16.8	95.1 ± 16.5	0.007	3.4 ± 7.0
TE	94.2 ± 17.5	98.4 ± 16.7	0.002	4.1 ± 7.5
HG	96.7 ± 17.5	100.2 ± 19.3	0.004	3.4 ± 5.4
Total peripheral resistance (dyn s/cm$^{5)}$				
SQ	1950 ± 1143.4	1682.3 ± 788	0.012	− 260 ± 570
LCMT	1840 ± 820.4	1796.5 ± 855	0.298	− 43.2 ± 234
WBT	1883 ± 932.5	1922.9 ± 940	0.215	39 ± 177
HeR	1961 ± 981.1	1907 ± 924	0.200	− 53 ± 235
TE	1934.4 ± 885	1951 ± 964.6	0.584	17.2 ± 179
HG	1618 ± 731	1744.4 ± 759.8	0.002	120 ± 159

SQ squatting, *LCMT* leg crossing and muscle tensing, *WBT* whole-body tensing, *He* heel raising, *TE* toe extension, *HG* handgrip

chemoreflexes in working muscles. Local sympathicolysis in contracting muscles results in local vasodilation and total vascular resistance remains unchanged

Pattern 2: Increase in TPR, CO is unchanged. This mechanism was observed in unilateral HG. Because of smaller muscular mass involved, functional sympathicolysis in working muscles is not able to overcome vasoconstriction in the other vascular beds. TPR is thus increased

Pattern 3: Increase in CO with simultaneous decrease in TPR. This pattern was observed in SQ. Principal mechanism is profound increase in SV mainly due to increased venous return to the heart by mechanical compression. Sympathetic activity seems to be decreased (as reflected by decrease in HR a TPR). Decreased sympathetic activity can be explained by increased venous return leading to atrial distension (Bainbridge reflex). Other possible mechanism is baroreceptor activation resulting from increased SV. In this pattern, mechanical compression of veins seems to play the more important role than reflex activity

ICM efficacy during HUT

Control HUT was carried out in 33 patients, vasovagal reaction was induced in 30 patients.

In three patients, control HUT was negative in term of vasovagal reaction (Fig. 4).

During first presyncopal symptoms, patients were instructed to perform ICM, which appeared most effective during teaching phase of the study. This was LCMT in 22 patients, WBT in 7 patients, and HeR in 1 patient.

In 14 patients (47%), ICM completely aborted syncope obviating the need for interruption of HUT. SBP,

Table 2 Time to peak mean arterial pressure in various ICM

	SQ	LCMT	WBT	HR	TE	HG
t (peak) [s]	3.6 ± 1.3	5.3 ± 2.1	4.9 ± 3.2	5.3 ± 2.7	5.3 ± 2.4	7.8 ± 3.5

SQ squatting, *LCMT* leg crossing and muscle tensing, *WBT* whole-body tensing, *He* heel raising, *TE* toe extension, *HG* handgrip

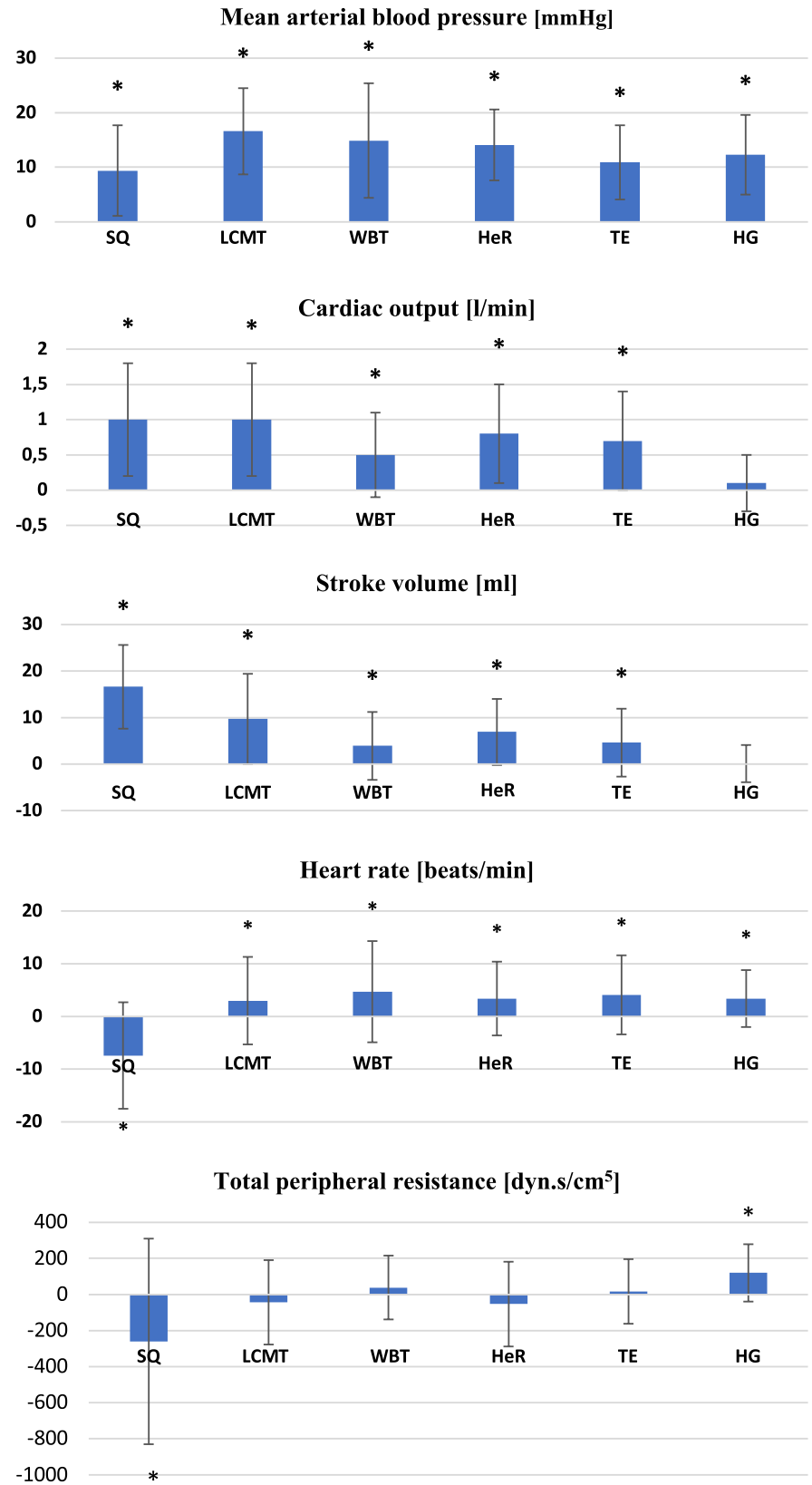

Fig. 3 Change in hemodynamic parameters during ICM (difference of values before and during ICM). *SQ* squatting, *LCMT* leg crossing and muscle tensing, *WBT* whole-body tensing, *HR* heel raising, *TE* toe extension, *HG* handgrip

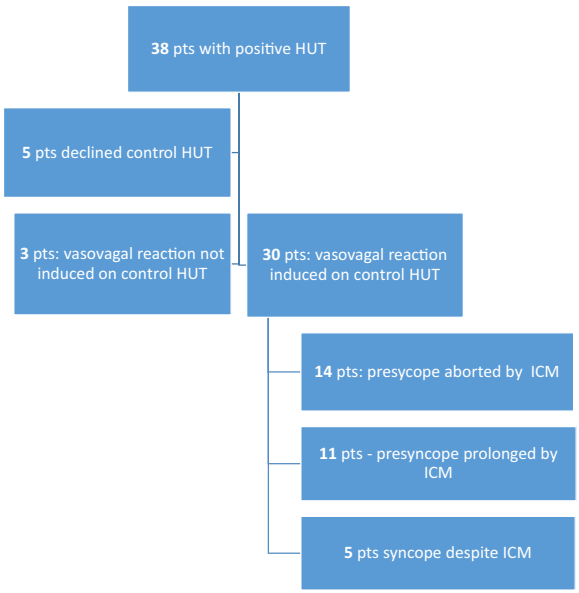

Fig. 4 ICM efficacy during HUT. *HUT* head-up tilt test, *ICM* isometric counter maneuver

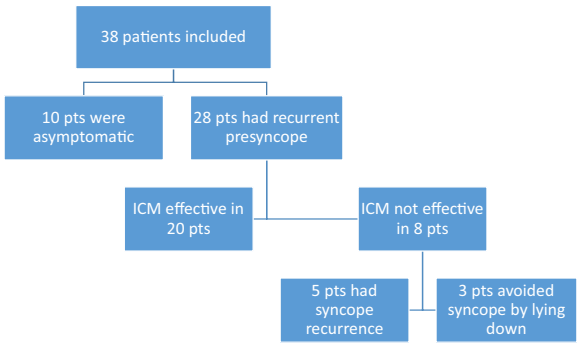

Fig. 5 Clinical follow-up results. *HUT* head-up tilt test, *ICM* isometric counter maneuver

DBP, and MAP were significantly increased during ICM (SBP 72.1 ± 15.1 mmHg vs. 124.6 ± 23 mmHg, $p < 0.0001$; DBP 51.3 ± 12.3 mmHg vs. 83.5 ± 16.4 mmHg, $p < 0.000$;, MAP 58.7 ± 13.2 mmHg vs. 96.7 ± 18.4 mmHg, $p < 0.0001$). CO increased (3 ± 1 l/min vs. 5.2 ± 1.6 l/min, $p < 0.0001$), and this rise was based mainly on SV increase (31.9 ± 9.2 ml vs. 47.1 ± 11.6, $p < 0.0001$. HR reaction was different in vasovagal reaction with cardioinhibition compared to vasovagal reaction with pure vasodepression. In the former type (VASIS type 1 and 2), HR increased (90.1 ± 28.5/min vs. 112.1 ± 23.2/min, $p < 0.001$. In the later type (VASIS 3), HR tended to decline (115.7 ± 25.6/min, vs. 111.6 ± 21.8/min; $p =$ n.s.). TPR remained unchanged during ICM during vasovagal reaction (1766 ± 675 dyn s/cm^5 vs. 1666 ± 715 dyn s/cm^5, $p = 0.248$).

In 11 patients (37%), application of ICM prolonged presyncopal period, during ICM, consciousness was preserved, but finally, HUT should be interrupted and patient were tilted back to supine position because of inability to continue the maneuver or because of imminent syncope.

In 5 patients (17%), ICM were ineffective, and syncope occurred despite performing ICM. These patients tended to be older than another 25 patients in which ICM was effective (42.2 ± 19 years vs. 34.3 ± 14.9 years, $p = 0.30$) and they experienced more syncopal episodes (9.8 ± 8.2 vs. 3.7 ± 3.3, $p = 0.007$). During the follow-up period (26 ± 7.5 months), none of them had recurrent syncope. Three from these five patients experienced presyncope and ICM were effective in preventing syncope.

Clinical follow-up

Thirty-eight patients were followed for the mean period of 26 ± 7 months. In 10 from 38 patients, no symptoms occurred during follow-up. In 28 from 38 patients (73%), symptoms (presyncope) recurred (Fig. 5).

In 20 from 28 (71%) patients with presyncope, ICM was effective; presyncope was aborted in standing position. In three patients, ICM prolonged presyncopal symptoms, but patients had to lie down to abort presyncope and prevent syncope. In 5 from 28 patients, ISPM was not effective and syncope occurred.

In total, syncope recurred in 5 of 38 patients during 21 month follow-up period (13%). Total syncope burden in the group was reduced from 22 episodes/year to 3.4 episodes/year. Per patient syncope burden was reduced from 0.57 episodes/year to 0.08/year.

Quality of life after 3 months of ICM training

SF-36 questionnaire

SF-36 questionnaire was administered in the beginning of the study and after 3 months of ICM training. Questionnaire was completed by 27 patients (9 men, 18 women, and mean age 36.0 ± 14.8). QOL significantly improved in all subscales (Table 3).

Syncope Functional Status Questionnaire (SFSQ)

SFQS was completed in 31 pts (10 men, 21 women, and mean age 36.5 ± 14.8 years). Significant improvement was observed in impairment score (IS, $p < 0.001$), fear/worry score (FWS, $p < 0.001$), hope score (HS, $p = 0.006$), and syncope dysfunction score (SDS, $p < 0.001$). No significant improvement was noted in control score (CS, $p = 0.48$) (Table 3).

Table 3 Quality of life

	Before ICM training	After ICM training	Significance (*p*)
SF-36 questionnaire			
Physical functioning	65.2 ± 17.8	73.9 ± 15.3	< 0.001
Social functioning	76.1 ± 18.3	88.1 ± 16.1	< 0.001
Role limitation due to physical health	52.8 ± 35.6	90.7 ± 19.8	< 0.001
Role limitation due to emotional problems	72.9 ± 35.6	84 ± 26.7	0.017
Mental health	71.9 ± 15.1	79.9 ± 14.5	0.009
Vitality	52.4 ± 19	64.1 ± 18.9	0.010
Bodily pain	80.3 ± 22.3	88.8 ± 19.8	0.002
General health	59.9 ± 17.6	73.4 ± 19.4	< 0.001
Physical component summary	64.2 ± 16.3	77.8 ± 14.8	< 0.001
Mental component summary	65.6 ± 14.7	75.7 ± 15.2	0.001
Syncope Functional Status Questionnaire (SFSQ)			
Control score (CS)	52.5 ± 22.9	49.3 ± 30.2	0.48
Hope score (HS)	18.8 ± 21.6	9.6 ± 13	0.006
Impairment score (IS)	28.4 ± 21.7	11.0 ± 15.2	< 0.001
Fear/worry score (FWS)	49.1 ± 28.1	27.6 ± 23.4	< 0.001
Syncope dysfunction score (SDS)	38.8 ± 19.7	19.3 ± 14.7	< 0.001

SF36 Short Form 36, *SFSQ* Syncope Functional Status Questionnaire

Discussion

The beneficial effect mechanism of ICM in patients with VVS is based on increase in mean arterial pressure (MAP) during isometric muscle contraction. This leads to augmentation of brain perfusion during presyncope and prevents loss of consciousness.

Although all maneuvers in our study significantly increased MAP, the efficacy of various ICM was different. Most marked increase in MAP was present in LCMT and WBT. Those two maneuvers were most effective and were selected for biofeedback training in majority of patients. Interestingly, SQ which is commonly recommended as alternative to horizontalization of the patient was the least efficient maneuver. On the other hand, the effect of SQ was fastest from all ICM and this maneuver may be, therefore, appropriate especially in patients with short presyncopal phase. Duration of presyncope is an important limiting factor of ICM efficacy. Prodromal symptoms should be sufficiently long to provide enough time for the patient to recognize them and to perform countermeasure maneuvers. The absence of prodromal symptoms and/or declined ability to recognize them are more common in elderly patients. Short duration of presyncope and older age (62 + 13 years) have decreased the efficacy of ICM in ISSUE 3 study population [14].

Muscular contraction increases sympathetic nerve activity due to activation of mechano- and chemoreflexes in working muscles. In addition, central neural commands and baroreflex mechanisms play a role. Increase in muscle sympathetic nerve activity is observed not only in contracting muscles, but also in non-contracting muscles. The magnitude of sympathetic activation is dependent on intensity of contraction [15]. Blood pressure increase in mainly mediated by increased CO. Total vascular resistance remained unchanged. This can be explained by the phenomenon called functional sympathicolysis. By the action of muscle metabolites (ATP, NO, and prostaglandins), local vasodilation and decreased resistance in contracting muscles are present. Functional sympathicolysis is considered a mechanism optimizing muscle blood flow during exercise [16].

Underlying hemodynamic mechanisms differ between various ICM as shown in the present study. The most common hemodynamic mechanism in our study was the increase in CO as a result of sympathetic stimulation. Different mechanisms were involved in HG and SQ.

In unilateral handgrip, TPR raised, which can be attributed to small mass of working muscles. Vasodilation is present only in a small part of vascular bed, and thus, vasoconstriction due to sympathetic stimulation is prevailing. Unilateral handgrip was an efficient maneuver in our study in contrast to some previously published reports [12]. Finally, in SQ, we observed decrease in TPR and HR. The main mechanism of increased CO was mechanical—increased SV due to augmented venous return resulting from mechanical compression of calf, reflex mechanisms play a minor role.

Effectivity of ICM can be assessed by their ability to abort syncope induced in laboratory conditions (during

HUT) in real life (spontaneous episodes. Effectivity of ICM was tested during tilt-induced vasovagal reaction in several previously published studies. In our study, ICM completely aborted presyncope in 47% of patients. Only 5 patients experienced syncope during HUT despite application of ICM. These patients were older and more symptomatic. Effectivity of ICM declines with age. The probability of syncope recurrence positively correlates with the number of syncopal episodes. This means that these five patients had higher risk of syncope recurrence than the rest of study population. Interestingly, no of these five patients experienced syncope during nearly 2 year follow-up period. It is known that the effectivity of pharmacological therapy cannot be predicted by tilt testing results [17]. Similar observation was made (although on small number of patients) in our study regarding ICM—effectivity of ICM probably cannot be predicted by their efficacy during tilt testing.

Syncope recurred in our group of patients in only 5 from 38 patients during mean 26 month period (13%). In all patients, syncope recurred despite applied ISPM. This recurrence rate of syncope was lower in our study than published data. In the large multicenter study, PC trial syncope recurred in 32% of patients, which was significantly less when compared to patients who were treated by conventional non-pharmacological treatment (avoiding triggers, increased fluid, and salt intake − 51%) [1]. Recurrence rate in non-randomized studies was 23–42% [6, 14, 18].

QOL is significantly reduced in patients with VVS and frequent syncopal recurrences [19, 20]. Data about effect of non-pharmacological treatment on QOL are limited. Romme reported improvement in QOL during non-pharmacological therapy which included also ICM after 3 months, which persisted also after 12 and 18 months. On contrary to our results, this improvement was present in Physical Component Score but not in Mental Summary Component Score [18].

Recurrence of presyncope in our study group was high and 73% of patient experienced symptoms during follow-up. It seems that regular ICM training is not able to reduce the number of presyncopal attack. The effectivity of ICM can be seen in reducing the number of syncope. ICM was able to prevent syncope in 71% of patients with presyncope.

The present study has limitations. The study is non-randomized, unable to compare the benefit of ICM to other treatment modalities. The observation period of 3 months is relatively short and the number of the patients is relatively small.

In conclusion, ICM were highly effective in preventing syncopal recurrences and improving quality of life in patients with VVS. ICM did not have uniform hemodynamic pattern, but all maneuvers were effective in increasing blood pressure including those involving smaller group of muscles. Selection of specific ICM should be individual according to its efficacy, ability of the patient to perform it, and with respect to specific circumstances of syncope occurrence.

Abbreviations

CO: cardiac output; CS: control score; DBP: diastolic blood pressure; FWS: fear/worry score; HeR: heel raising; HG: handgrip; HR: heart rate; HS: hope score; HUT: head-up tilt; ICM: isometric counter-pressure maneuvers; IS: impairment score; LCMT: leg crossing with muscle tensing; MAP: mean arterial pressure; QOL: quality of life; SBP: systolic blood pressure; SDS: syncope dysfunctions score; SF36: Short Form 36; SFSQ: Syncope Functional Status Questionnaire; SQ: squatting; SV: stroke volume; TE: toe extension; TPR: total peripheral resistance; VASIS: Vasovagal Syncope International Study; VVS: vasovagal syncope; WBT: whole-body tensing.

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Authors' contributions

PM: study design, analysis and interpretation of data, and manuscript preparation. EM: data acquisition, analysis and interpretation of data, and manuscript preparation. ZL: analysis and interpretation of data, and manuscript preparation. All authors read and approved the final manuscript.

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All persons gave their informed consent to participate. Study was performed in accordance with Declaration of Helsinki and was approved by ethics committee VUSCH.

Consent for publication

All authors agree with publication of the manuscript.

Competing interests

The authors declare that they have no competing interests.

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References

1. van Dijk N, Quartieri F, Blanc JJ, et al. Effectiveness of physical counterpressure maneuvers in preventing vasovagal syncope: the Physical Counterpressure Manoeuvres Trial (PC-Trial). J Am Coll Cardiol. 2006;48(8):1652–7.
2. Wieling W, van Dijk N, Thijs RD, et al. Physical countermeasures to increase orthostatic tolerance. J Intern Med. 2015;277(1):69–82.
3. Groothuis JT, van Dijk N, Ter Woerds W, Wieling W, Hopman MT. Leg crossing with muscle tensing, a physical counter-manoeuvre to prevent syncope, enhances leg blood flow. Clin Sci. 2007;112(3):193–201.
4. Brignole M, Croci F, Menozzi C, et al. Isometric arm counter-pressure maneuvers to abort impending vasovagal syncope. J Am Coll Cardiol. 2002;40(11):2053–9.
5. Krediet CT, de Bruin IG, Ganzeboom KS, et al. Leg crossing, muscle tensing, squatting, and the crash position are effective against vasovagal reactions solely through increases in cardiac output. J Appl Physiol. 2005;99(5):1697–703.

6. Krediet CT, van Dijk N, Linzer M, van Lieshout JJ, Wieling W. Management of vasovagal syncope: controlling or aborting faints by leg crossing and muscle tensing. Circulation. 2002;106(13):1684–9.
7. Croci F, Brignole M, Menozzi C, et al. Efficacy and feasibility of isometric arm counter-pressure manoeuvres to abort impending vasovagal syncope during real life. Europace. 2004;6(4):287–91.
8. Brignole M, Moya A, de Lange FJ, et al. 2018 ESC Guidelines for the diagnosis and management of syncope. Eur Heart J. 2018;39(21):1883–948.
9. Krediet CT, Go-Schon IK, Kim YS, et al. Management of initial orthostatic hypotension: lower body muscle tensing attenuates the transient arterial blood pressure decrease upon standing from squatting. Clin Sci. 2007;113(10):401–7.
10. Krediet CT, van Lieshout JJ, Bogert LW, et al. Leg crossing improves orthostatic tolerance in healthy subjects: a placebo-controlled crossover study. Am J Physiol Heart Circ Physiol. 2006;291(4):H1768–72.
11. Idiaquez J, Idiaquez JF, Iturriaga R. Cardiovascular responses to isometric handgrip exercise in young patients with recurrent vasovagal syncope. Auton Neurosci. 2018;212:23–7.
12. Kim KH, Cho JG, Lee KO, et al. Usefulness of physical maneuvers for prevention of vasovagal syncope. Circ J. 2005;69(9):1084–8.
13. van Dijk N, Boer KR, Wieling W, Linzer M, Sprangers MA. Reliability, validity and responsiveness of the syncope functional status questionnaire. J Gen Intern Med. 2007;22(9):1280–5.
14. Tomaino M, Romeo C, Vitale E, et al. Physical counter-pressure manoeuvres in preventing syncopal recurrence in patients older than 40 years with recurrent neurally mediated syncope: a controlled study from the Third International Study on Syncope of Uncertain Etiology (ISSUE-3) dagger. Europace. 2014;16(10):1515–20.
15. Boulton D, Taylor CE, Macefield VG, Green S. Effect of contraction intensity on sympathetic nerve activity to active human skeletal muscle. Front Physiol. 2014;5:194.
16. Thomas GD. Functional sympatholysis in hypertension. Auton Neurosci. 2015;188:64–8.
17. Morillo CA, Klein GJ, Gersh BJ. Can serial tilt testing be used to evaluate therapy in neurally mediated syncope? Am J Cardiol. 1996;77(7):521–3.
18. Romme JJ, Reitsma JB, Go-Schon IK, et al. Prospective evaluation of non-pharmacological treatment in vasovagal syncope. Europace. 2010;12(4):567–73.
19. Rose MS, Koshman ML, Spreng S, Sheldon R. The relationship between health-related quality of life and frequency of spells in patients with syncope. J Clin Epidemiol. 2000;53(12):1209–16.
20. Giada F, Silvestri I, Rossillo A, et al. Psychiatric profile, quality of life and risk of syncopal recurrence in patients with tilt-induced vasovagal syncope. Europace. 2005;7(5):465–71.

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