

1 **Effect of lifestyle changes after percutaneous coronary intervention on**
2 **revascularization**

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16

17 **Short title:**

18 Life's simple 7 in secondary prevention

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1 **Abstract**

2 **Objective:** Whether optimal cardiovascular health metrics may reduce the risk
3 of cardiovascular events in secondary prevention is uncertain. The study was
4 conducted to evaluate the influence of lifestyle changes on clinical outcomes
5 among the subjects underwent percutaneous coronary intervention (PCI).

6 **Methods:** The study group consists of 17,099 consecutive PCI patients. We
7 recorded data on subject lifestyle behavior changes after their procedure.
8 Patients were categorized as ideal, intermediate or poor CV health according
9 to a modified Life's Simple 7 score (on body mass, smoking, physical activity,
10 diet, cholesterol, blood pressure and glucose). Multi-variable COX regression
11 was used to evaluate the association between CV health and revascularization
12 event. We also tested the impact of cumulative cardiovascular health score on
13 re-occurrence of cardiovascular event.

14 **Results:** During a 3-years median follow-up, 1,583 revascularization events
15 were identified. The observed revascularization rate was 8.0%, 9.3% and 10.6%
16 in the group of patients with optimal (modified-Life's Simple 7 score of 11-14),
17 average (score=9 or 10) or inadequate (less or equal than 8) CV health,
18 respectively. After multivariable analysis, the adjusted hazard ratios were 0.83
19 (95%CI: 0.73-0.94) and 0.89 (95%CI: 0.79-0.99) for patients with optimal and
20 average lifestyle changes comparing with the inadequate tertile (P for
21 trend=0.003). In addition, each unit increase in above metrics was associated
22 with a decrease risk of revascularization (HR, 0.96; 95% confidence interval,

1 0.93-0.98; P<0.001).

2 **Conclusion:** Ideal CV health related to lower incidence of cardiovascular
3 events, even after the percutaneous coronary intervention. Revascularization
4 can be reduced by lifestyle changes. The cardiovascular health metrics could
5 be extrapolated to secondary prevention and need for further validation.

6

7 **Key Words:** Cardiovascular health metrics, Secondary prevention,
8 Revascularization

9

1 **Introduction**

2 Ideal cardiovascular health (CVH) has been proposed by the American
3 Heart Association (AHA) and used to measure population health.¹ The seven
4 risk factors (Life's Simple 7) that people can improve through lifestyle changes
5 included four health behaviors (stop smoking, eat better, get active and lose
6 weight) and three health factors (manage blood pressure, control cholesterol
7 and reduce blood sugar). Cumulative evidence already demonstrated the AHA
8 ideal CVH metrics could be used for cardiovascular health factors assessment,
9 health promotion and a tool to predict mortality and cardiovascular diseases
10 (CVD) risk.^{2,3} The steep gradient relationship between ideal CVH metrics and
11 CVD was similar across different region and diverse race-ethnic groups.⁴⁻⁸

12 The concept of ideal CVH metrics was originally defined and intended to
13 use for primordial prevention among general population.^{1,9} Although the
14 inverse relationship between ideal CVH and CVD incidence was also well
15 documented for primary prevention,¹⁰⁻¹⁵ the evidence in secondary prevention
16 is limited.^{16,17} It should be noticed that most of the individual components in
17 ideal CVH metrics associated with reduced clinical event risk for the subject
18 with established CVD.^{18,19} However, few data are available on the relationship
19 between having ideal risk factor profile using a composite measure and the
20 recurrence of cardiovascular events.

21 Therefore, our aim in this study is to investigate the influence of ideal CVH
22 as risk factor of cardiovascular outcomes for secondary prevention. The study

1 was based on a cohort of patients who underwent percutaneous coronary
2 intervention. We hypothesized that the subjects with optimal CVH would be
3 less likely to develop cardiovascular events during their follow-up period.

4

5 **Methods**

6 The data that support the findings of this study are available from the
7 corresponding author upon reasonable request.

8

9 ***Study design and population***

10 The current analysis was based on an established cohort from Fuwai
11 hospital. A total of 19,506 consecutive patients with successful percutaneous
12 coronary intervention were recruited. Further inclusion criteria for analysis
13 were: subject should have at least one stent implantation, one year or longer
14 post procedure follow up, alive, complete the questionnaire during follow-up
15 visit. Finally, there were 17,099 (87.7%) patients fulfill the above requirements.
16 The study protocol was approved by ethical committee and formal inform
17 consent was obtained from every study participants. Details of the study
18 design have been previously described.²⁰

19

20 ***Follow up***

21 Follow-up was conduct by a group of trained investigators. Standard
22 operation procedure was fixed after a small scale pilot study. Non-responder

1 was the subject who can not be reached after 3 contacts on different days
2 within one week. Both lifestyle changes related information and clinical
3 outcomes were collected in a standardized questionnaire. A 5% random
4 re-sampling process was carried out to validate the reliability of the data
5 collected by the above interview procedure (kappa coefficients were from 0.91
6 to 0.97 for different items in the questionnaire).

7

8 ***Exposure and outcome***

9 Pre-specified options (exp. greater, no change or less) had been used to
10 reflect the lifestyle behavior changes after PCI procedure compare with the
11 situation before procedure. A modified Life's Simple 7 score (on body mass,
12 smoking, physical activity, diet, cholesterol, blood pressure and glucose) had
13 been developed according to AHA recommendation (giving 2 points for ideal, 1
14 point for intermediate and 0 point for poor). For physical activity, 2=longer,
15 1=no change and 0=shorter. The blood pressure, cholesterol and glucose
16 were used the same rule, 2=better controlled than before, 1=no change and
17 0=worsen. Healthy diet covered fresh vegetables/fruits, salt and meat. If
18 patient reported more fresh vegetables/fruits, less salt and meat consumption,
19 the score for healthy diet was 2. On the opposite, if a patient had less
20 vegetables/fruits, more salt or meat compare with before procedure status, the
21 healthy diet score was 0. The remained situations were assigned 1 for diet
22 score. For weight changes, 2=no change, 1=loss weight and 0=weight

1 increase. If patient was a non-smoker or they quit smoking at least 1 year
2 before their procedure, the non-smoking score was 2. For smokers and other
3 former smokers, the non-smoking score were 0 and 1 respectively. After obtain
4 of the modified Life's Simple 7 score, both cumulative score (ranged from 0 to
5 14) and its tertiles (1st tertile: inadequate CVH, 2nd tertile: average CVH, 3rd
6 tertile: optimal CVH) were used to estimate the impact on re-occurrence of
7 cardiovascular event. The key clinical outcome in current analysis was any
8 revascularization during the follow-up period.

9

10 ***Statistical analysis***

11 Means and standard deviations were used as descriptive analysis for
12 continuous variables. Categorical variables used frequencies and proportions.
13 The patients were divided into 3 groups according to their tertiles of
14 modified-Life's Simple 7 score. One-way ANOVA or Chi-square test was used
15 for between groups comparison where appropriate. To evaluate the potential
16 association between modified-Life's Simple 7 score and revascularization, the
17 uni-variable and multi-variable COX regression model had been used. The
18 covariates were fixed according to published literature (included demographic,
19 health status, family health history and procedure related characteristics etc.).
20 Firstly, the trend between each ideal CVH group had been tested. After that,
21 dummy variables were used to represent the patient with optimal (11-14) and
22 average (score=9 or 10) modified-Life's Simple 7 score and the lowest tertile

1 (inadequate: score less or equal than 8) group was used as reference. In
2 addition, the risk of revascularization for each unit increase in ideal CVH
3 metrics was estimated under the same confounding variables adjustment
4 model. The analysis software was SAS®9.4 and significant level in this study
5 was 2-sided 0.05.

6

7 **Results**

8 ***Characteristics of study population***

9 A total of 17,099 percutaneous coronary intervention patients (78.7% male)
10 with a mean age of years 57.5 ± 10.4 were enrolled in this analysis. Two-thirds
11 of the patients were diagnosed as unstable angina. The proportion of
12 hypertension, dyslipidemia and diabetes among the overall population was
13 50.0%, 32.0% and 18.5%, respectively. A total of 1,583 revascularization
14 events during the follow-up period had been identified. The participants were
15 grouped by the occurrence of revascularization (Yes/No). Detail demographic
16 characteristics are listed in Table 1.

17

18 ***Lifestyle behavior (ideal cardiovascular health metrics) changes***

19 Table 2 shows the prevalence of each component of cardiovascular health
20 metrics. Most subjects (72.8%) could manage and maintain weight at
21 appropriate range after their PCI procedure. More than half of the patients
22 were non-smoker or permanent quit smoking. Over forty percent subjects

1 moved to a healthy diet behavior after their discharge from hospital. The
2 control of blood pressure, cholesterol and blood glucose was achieved in
3 59.5%, 55.7% and 22.1% among the overall participants, respectively. The
4 proportions of each individual ideal CVH component among the tertile groups
5 (determined by the cumulative score: inadequate, average and optimal) had
6 also been described.

7

8 ***Uni- and multi-variable logistic regression analysis***

9 Firstly, we simply counted the cumulative score of ideal Life's Simple 7
10 components. The hazard ratio of 1 unit change on the ideal CVH metrics was
11 0.96 (95% CI, 0.93 to 0.98) after the adjustment of potential confounding
12 variables. The multivariable COX regression model shows, comparing with the
13 inadequate category (the lowest tertile on lifestyle behavior modification), the
14 hazard ratios on revascularization for patients in average and optimal ideal
15 CVH group were 0.89 (95% CI, 0.79 to 0.99) and 0.83 (95% CI, 0.73 to 0.94),
16 respectively. The P for trend was 0.003. The relationships between each
17 individual ideal CVH components and repeated revascularization event were
18 ranged from 0.79 to 1.05 (hazard ratios by multivariable adjusted model).
19 Detail results are described in Table 3.

20

21 **Discussion**

22 ***Key findings and study strengths***

1 Our study suggested subjects in optimal ranges of Life's Simple 7 (LS7)
2 had a lower risk of revascularization compared with people in poor ranges
3 during a 3 years follow-up period after percutaneous coronary intervention.
4 Each additional ideal cardiovascular health metrics was associated with 4%
5 lower risks of repeated revascularization event. To the best of our knowledge,
6 this study is the first to investigate the association of ideal cardiovascular
7 health metrics with clinical outcome among participants underwent
8 percutaneous coronary intervention.

9

10 ***Comparisons with published literature***

11 Current percutaneous coronary intervention studies are more focused on
12 examining the efficacy of different treatment strategies, of emerging or existing
13 devices and of the value of coronary physiology or intravascular imaging in
14 PCI planning.²¹ Evidence regarding the links between healthy lifestyle and
15 cardiometabolic consequences in people who had coronary interventions is
16 fairly sparse. Potential benefit of Life's Simple 7 had been investigated among
17 myocardial infarction patients. The findings suggested ideal CV health at
18 middle age was associated with better prognosis after MI in later life.²²
19 However, the impact of ideal cardiovascular health metrics among subjects
20 with different risk strata has not been well established. In a recent large scale
21 nationwide prospective cohort study, participants with prediabetes or diabetes
22 who had five or more ICVHMs (ideal cardiovascular health metrics) exhibited

1 lower or no significant excess risk of CVD events compare with those with
2 normal glucose regulation. Compared with 1 ideal CVH metric or none, 5 or
3 more ideal metrics were associated with 58% and 61% lower CVD risks
4 among participants with prediabetes and diabetes, respectively.²³ The
5 attenuated effect size observed in our study may attribute to the heterogeneity
6 between different populations. Our study extends previous findings by
7 comprehensively assessing 7 lifestyle risk factors in secondary prevention for
8 revascularization in relation to lifestyle factors individually and in combination.

9 Baseline measurement of ideal CVH and the longitudinal maintenance of
10 CVH were both significant associated with CVD progression in general
11 population.^{24,25} However, it should be noticed the prevalence of ideal
12 cardiovascular health metrics was systematic different in secondary
13 prevention.²⁶ For example, the prevalence of smoking in general population
14 has been reported to be 52.9%.²⁷ But the proportion for quit smoking was only
15 8%.²⁸ In contrast, the smoking cessation rate was 40% to 94% at 1 year and
16 37% at 5 years after the ischemic event.^{29,30} Further, a pooled cohorts
17 consisted of 661,137 participants indicate a benefit threshold at approximately
18 3 to 5 times the recommended leisure time physical activity.³¹ Around one fifth
19 participants could meet the above intensity of physical activity for general
20 population. Compare with our study, the observed proportion of patient had
21 increased level of physical activities after the PCI procedure was around thirty
22 percent (27.7%). Cardiovascular intervention is an opportunity to reassess the

1 risk factor control and an optimal time when patients and family members are
2 more likely to be receptive to lifestyle modification.³² Healthcare professionals
3 should encourage PCI patient to perform more ideal CVH metrics.

4 Although cardiac rehabilitation is strongly recommended following
5 myocardial infarction, which components of rehabilitation are most beneficial is
6 unclear.³³ As one key component of cardiovascular health metrics, smoking
7 increases the risk of virtually all cardiovascular disease subtypes.³⁴ Smoking
8 cessation had been demonstrated as a modifiable risk factor both for primary
9 and secondary prevention of stroke.³⁵⁻³⁷ However, the effect of single ideal
10 CVH metrics maybe partly attributable to other lifestyle behavior changes (eg.
11 subject has more exercise and healthier diet at the same time with smoking
12 cessation).^{36,38} The combination of cardiovascular health metrics may had joint
13 impact on the endothelialization and inflammatory process. This proposed
14 phenomenon was corresponding to the underling mechanism of restenosis of
15 the coronary arteries.^{39,40} Further basic researches are required to validate the
16 above hypothesis.

17

18 ***Study limitations***

19 Our study has several limitations. First, we could not fully rule out all the
20 residual and unmeasured confounders, such as genetic predisposition,
21 medications, and psychological status and possible reverse causation.
22 Nevertheless, the sensitivity analysis taking into account this potential bias

1 showed similar results. Second, the cardiovascular health metrics were
2 modified according to the feature of follow-up process in this study. The
3 changes in the metrics over time (health check-up periods) could not be
4 accounted for in this study. Further, participants were excluded if their
5 cardiovascular health metrics missing, so the selection bias may also exist.
6 Third, measurement errors in self-reported assessments of lifestyle changes
7 were inevitable, although the accuracy of self-reports information had been
8 demonstrated through a 5% re-sampling validation process. The use of
9 prospectively collected, cumulatively averaged values based repeated
10 assessments would be reduced the effect of random measurement error. By
11 the above reasons our results should be interpreted cautiously.

12

13 ***Conclusions***

14 In this observational study, patients underwent percutaneous coronary
15 intervention who achieved a greater number of ideal CVH metrics exhibited
16 lower risk of repeated revascularization event. Our findings emphasize the
17 importance of promoting the adherence to ideal CVH metrics in the population
18 with established cardiovascular disease. We believe further researches
19 addressing this hypothesis are warranted.

20

1 **Acknowledgments**

2 The authors thank the staff and the participants for their valuable contribution.

3 The preliminary data of this study had been presented as a poster in the

4 International Society of Hypertension annual meeting.

5

6 **Sources of Funding**

7 None.

8

9 **Disclosures**

10 None.

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1 **Table 1 Baseline Characteristics of Participant with or without**
 2 **Revascularization**

Variables	Revas. (N=1583)	No Revas. (N=15516)	P value
Age, y, mean±SD	58.1±10.4	57.4±10.4	0.023
Male, n (%)	1259 (79.5)	12201 (78.6)	0.406
Unstable angina, n (%)	1028 (64.9)	10228 (65.9)	<0.001
Prior myocardial Infarction, n (%)	570 (36.0)	4755 (30.7)	<0.001
Family history of CHD, n (%)	88 (5.6)	611 (3.9)	0.002
Hypertension, n (%)	911 (57.6)	7636 (49.2)	<0.001
Dyslipidemia, n (%)	574 (36.3)	4905 (31.6)	<0.001
Diabetes, n (%)	349 (22.1)	2821 (18.2)	<0.001
LVEF<40%, n (%)	683 (43.2)	8516 (54.9)	<0.001
Reference Vessel Diameter, mm, mean±SD	3.1±0.6	3.2±1.9	<0.001
Lesion length, mm, mean±SD	26.1±15.7	25.4±14.6	0.078
Diameter Stenosis, %, mean±SD	89.7±7.7	88.4±8.0	<0.001
Calcification, n (%)	72 (4.6)	534 (3.4)	0.023
Total occlusion, n (%)	469 (29.6)	3231 (20.8)	<0.001
Trans-radial access, n (%)	1140 (72.0)	12495 (80.5)	<0.001
TIMI classification, n (%)			<0.001
0	421 (26.6)	3232 (20.8)	
1	75 (4.7)	648 (4.2)	
2	202 (12.8)	1945 (12.5)	
3	885 (55.9)	9691 (62.5)	

3

1 **Table 2 Prevalence of Ideal Cardiovascular Health Metrics**

	Overall (N=17099)	Inadequate (N=5267)	Average (N=6029)	Optimal (N=5803)
Physical activity				
-Poor	2785 (16.3)	1521 (28.9)	907 (15.0)	3572.8)
-Intermediate	9674 (56.0)	3254 (61.8)	3775 (62.6)	2545 (26.6)
-Ideal	4740 (27.7)	492 (9.3)	1347 (22.3)	2901 (61.2)
Blood pressure				
-Poor	1290 (7.5)	1000 (19.0)	250 (4.2)	40 (0.7)
-Intermediate	5642 (33.0)	3150 (59.8)	2179 (36.1)	313 (5.4)
-Ideal	10167 (59.5)	1117 (21.2)	3600 (59.7)	5450 (93.9)
Blood cholesterol				
-Poor	1371 (8.0)	1003 (19.0)	315 (5.2)	53 (0.9)
-Intermediate	6205 (36.3)	3348 (63.6)	2446 (40.6)	411 (7.1)
-Ideal	9523 (55.7)	916 (17.4)	3268 (54.2)	5339 (92.0)
Blood glucose				
-Poor	1977 (11.6)	1179 (22.4)	621 (10.3)	177 (3.1)
-Intermediate	11337 (66.3)	3751 (71.2)	4525 (75.1)	3061 (52.8)
-Ideal	3785 (22.1)	337 (6.4)	883 (14.7)	2565 (44.2)
Ideal BMI				
-Poor	2046 (12.0)	1098 (20.9)	700 (11.6)	248 (4.3)
-Intermediate	2599 (15.2)	1027 (19.5)	877 (14.6)	695 (12.0)
-Ideal	12454 (72.8)	3142 (58.7)	4452 (73.8)	4860 (83.6)
Healthy diet				
-Poor	818 (4.8)	543 (10.3)	207 (3.4)	68 (1.2)
-Intermediate	9035 (52.8)	3720 (70.6)	3592 (59.6)	1723 (29.7)
-Ideal	7246 (42.4)	1004 (19.1)	2230 (37.0)	4012 (69.1)
Ideal smoking status				
-Poor	3683 (21.5)	2003 (38.0)	1190 (19.7)	490 (8.4)
-Intermediate	4156 (24.3)	1557 (29.6)	1420 (23.6)	1179 (20.3)
-Ideal	9260 (54.2)	1707 (32.4)	3419 (56.7)	4134 (71.2)

2

1 **Table 3 Hazard Ratio (95% CI) of Revascularization According to**
 2 **Combined and Individual Ideal CVH Metrics**

	Univariable analysis	Multivariable analysis
Combined ideal CVH metrics		
- 1 unit change (Each 1-number increment in ICVHMs)	0.95 (0.93, 0.98)	0.96 (0.93, 0.98)
- Trend (P for trend instead)	0.90 (0.85, 0.96) <0.001	0.91 (0.85, 0.97) 0.003
- Average vs. Inadequate	0.88 (0.79, 0.99)	0.89 (0.79, 0.99)
- Optimal vs. Inadequate	0.81 (0.72, 0.92)	0.83 (0.73, 0.94)
Individual component of ideal CVH metrics – Physical activity		
- 1 unit change	0.92 (0.85, 0.99)	0.92 (0.85, 0.99)
- P for trend	0.038	0.037
Individual component of ideal CVH metrics - Blood pressure		
- 1 unit change	0.89 (0.82, 0.96)	0.90 (0.84, 0.97)
- P for trend	0.002	0.008
Individual component of ideal CVH metrics - Blood cholesterol		
- 1 unit change	0.88 (0.82, 0.95)	0.89 (0.83, 0.96)
- P for trend	0.001	0.004
Individual component of ideal CVH metrics - Blood glucose		
- 1 unit change	0.79 (0.72, 0.86)	0.79 (0.72, 0.86)
- P for trend	<0.001	<0.001
Individual component of ideal CVH metrics - Ideal BMI		
- 1 unit change	0.95 (0.89, 1.02)	0.94 (0.88, 1.01)
- P for trend	0.192	0.110
Individual component of ideal CVH metrics - Healthy diet		
- 1 unit change	0.98 (0.90, 1.06)	1.01 (0.92, 1.10)
- P for trend	0.586	0.885
Individual component of ideal CVH metrics - Ideal smoking status		
- 1 unit change	1.05 (0.98, 1.11)	1.05 (0.98, 1.12)
- P for trend	0.153	0.150

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