

Health and Productivity Management: Establishing Key Performance Measures, Benchmarks, and Best Practices

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Major areas considered under the rubric of health and productivity management (HPM) in American business include absenteeism, employee turnover, and the use of medical, disability, and workers' compensation programs. Until recently, few normative data existed for most HPM areas. To meet the need for normative information in HPM, a series of Consortium Benchmarking Studies were conducted. In the most recent application of the study, 1998 HPM costs, incidence, duration, and other program data were collected from 43 employers on almost one million workers. The median HPM costs for these organizations were \$9992 per employee, which were distributed among group health (47%), turnover (37%), unscheduled absence (8%), non-occupational disability (5%), and workers' compensation programs (3%). Achieving "best-practice" levels of performance (operationally defined as the 25th percentile for program expenditures in each HPM area) would realize savings of \$2562 per employee (a 26% reduction). The results indicate substantial opportunities for improvement through effective coordination and management of HPM programs. Examples of best-practice activities collated from on-site visits to "benchmark" organizations are also reviewed. (J Occup Environ Med. 2001;43:10-17)

The aggregate costs of providing health and productivity programs to workers have not been adequately assessed for American employers. Typically, employers examine their program costs one area at a time and are generally only able to report the organization's costs within any given benefit or program, such as group health, disability, or workers' compensation. Consequently, managers are generally unaware of the costs associated with other programs and are almost never able to estimate total health and related lost productivity costs for the organization.

Recently, several studies have emerged that highlight the relationship between employee health and well-being and consequent productivity gains or losses. For example, a study funded by the Health Enhancement Research Organization (HERO) showed that employees who are depressed and highly stressed cost employers significantly more in health care costs compared with those without these psychosocial risk factors.¹ Claxton et al² demonstrated that when workers are appropriately treated for depression, their rate of absenteeism drops. Cockburn et al³ documented differences in workers' productive output when treated for allergies with different types of antihistamines. Burton et al⁴ showed a direct relationship between modifiable health risk factors and work output for telephone call center operators at a bank. These and other studies have set a framework for future research that will more clearly

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connect employee health, organizational performance, and work output (ie, productivity). Thus, there is a growing body of literature suggesting that worker health and productivity are related and that effective management of one will positively impact the other.

When considering productivity losses associated with health care, direct costs (eg, those associated with the provision of medical insurance benefits, disability payments, workers' compensation losses) most likely represent only a fraction of what employers spend to keep workers healthy and on the job.⁵ We will show that when employers factor in indirect costs (such as those for replacement workers, overtime premiums, productivity losses related to unscheduled absences, and productivity losses of workers while on the job), the total health and productivity cost burden is increased significantly.

Recent labor shortages, attempts to consolidate corporate functions, and increased emphasis on expense management are some of the factors that have driven many organizations to organize diverse human resource and benefit functions in a more coordinated fashion. Many employers have introduced a new management approach that has been termed health and productivity management (HPM). HPM refers to the joint management of the many types of programs that employees may access when they are sick, injured, or balancing work/life issues. These include medical benefits, disability and workers' compensation programs, employee assistance programs (EAPs), paid sick leave, and occupational safety programs. HPM also refers to activities meant to enhance morale, reduce turnover, and increase on-the-job productivity.⁶

In this article, we describe the process for gathering key HPM measures from a diverse group of American employers who participated in our most recent benchmarking study. We detail how the data were collected, how the measures were developed, and

how "best-practice" targets were set. We also explain how quantitative data (from the survey phase of the study) were combined with qualitative information about HPM best practices (gathered through site visits at leading companies) to position the HPM model internally within organizations. The results reported suggest significant opportunities for other employers to better manage their health and productivity programs through collaborative efforts within their organizations. Just as important, the methods used to collect and evaluate HPM information presented within this report can be replicated at many other organizations, as a first step toward identifying opportunities for enhancing and coordinating the management of employee health and productivity.

Background

In the summer of 1996, representatives from a group of 17 Fortune 500 companies met in Chicago to discuss their individual and collective efforts in health and productivity management. The HPM benchmarking initiative grew out of an explicit need identified by this group of leading employers to identify comparative metrics and practices that would help them better understand the performance of their HPM programs. Subsequently, the first HPM Consortium Benchmarking Study was designed and implemented in April 1997.

The first study was a cooperative venture between The MEDSTAT Group (MEDSTAT) and The American Productivity & Quality Center (APQC). Most recently, the Institute for Health and Productivity Management was also included as a partner, as were three pharmaceutical companies, Pfizer, Pharmacia, and Schering-Plough. The HPM Consortium Benchmarking Study consisted of two phases.

Phase I: Quantitative Analysis

In this phase, a survey was administered to human resources or benefit staff at each participating organiza-

tion. The survey was designed to collect basic information about each organization's performance in the following HPM areas: health care benefits; EAPs; unscheduled absence; short- and long-term disability; workers' compensation; employee turnover; health, demand, and disease management programs; employee compensation; employee attitudes; and organizational productivity.

The focus of the survey was to gather specific performance data, including costs, incidence, and duration for each of these programs. Respondents supplied data about their actual experiences. Each participant's performance was then compared with norms and benchmarks that were internal (based on comparisons with other study participants) and external (obtained from public domain databases, reference documents, and other publications). Potential areas for improvement were identified, and dollar estimates of potential cost savings were calculated based on the difference between the organization's actual experience within each HPM area and the experience of organizations at the 25th percentile or better. The results of this study were reported to all participating organizations, individually and in aggregate, during a "knowledge transfer session" that culminated the study.

Phase II: Qualitative Analyses

This phase of the study focused on gathering qualitative information through site visits from organizations considered to use best practices in implementing HPM programs. Planning for site visits began with an organizing meeting in September 1997, at which the APQC/MEDSTAT study team and the participants agreed on the scope of the project. The study team developed specific discussion items to be addressed during site visits with best-practice organizations.

Planning for the September meeting began 1 month earlier with an

extensive review of secondary literature to identify organizations that have implemented innovative practices in HPM. The study team compiled the results of their investigations, which were used by participants to select best-practice organizations suitable for site visits.

The study team also developed a data collection tool and standard interview protocol to be used at site visits with innovative companies. The first set of visits was conducted in November and December 1977 and the second set during the same time period in 1998. The visits focused on three areas of inquiry: (1) factors that facilitated the implementation of an HPM agenda within an organization, (2) actual implementation processes, and (3) methods used to measure and evaluate program outcomes. Best-practice organizations selected for site visits in 1997 and 1998 were 3M Company, Applied Materials, Chevron Corporation, Coors Brewing Company, General Electric Company, Navistar International, Steelcase Inc, Texas Instruments Incorporated, and Union Pacific Railroad.

The overwhelming success of the earlier HPM benchmarking studies prompted MEDSTAT and APQC to improve and expand the study each year. In the third year of the study, the new study partners (Institute for Health and Productivity Management, Pfizer, Pharmacia, and Schering-Plough) became actively involved in the design and implementation of the project. After feedback from respondents, the quantitative survey was expanded to include new questions about related HPM program areas, including EAPs, on-site medical clinics, safety programs, disease management, clinical patterns, and work-life programs.

Described below are the methods used to develop key measures, the processes used to collect and compile data, and the results from the most recent study. For this application, 1998 data were collected and

analyzed. Results were reported to the 43 employer participants in March 2000. We supplemented the quantitative results with qualitative findings collected during site visits conducted with best-practice companies in 1998.

Study Objectives

The objectives of the HPM Consortium Benchmarking Study were to (1) provide sufficient quantitative information for an organization's management team to assess the relative magnitude of HPM expenditures across departments and functions within their organization; (2) compare program-specific results with norms and benchmarks so that opportunities for improvement could be quantified; (3) provide the foundation for building an internal business case for the HPM model and establishing broad priorities for key initiatives; and (4) serve as a catalyst for identifying information gaps that when filled, would allow organizations to better measure, monitor, and manage their HPM programs.

Data Source

A survey instrument was developed to collect key HPM metrics from participating organizations. The instrument was designed to capture basic core metrics so that results could be used to identify broad opportunities for action. Organizations were to provide data that would (or should) normally be available and accessible to top managers. The intent was to achieve the right balance of collecting enough meaningful information about each program while keeping the data collection requirements at a reasonable level. The survey instrument was designed for completion in no more than 2 days once it was distributed to the appropriate managers or departments within the organization.

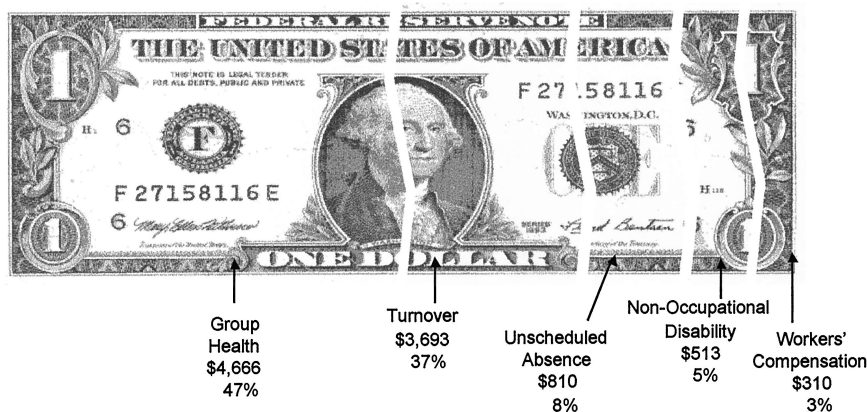
For the 1999/2000 study, 1998 calendar year data were obtained for the active employee population. HPM areas queried included: group health; EAPs; non-occupational dis-

ability; workers' compensation; on-site medical clinics; safety; health promotion, demand management, disease management; work/life management; employee attitude; turnover; productivity; and medical/clinical of relevance to the organization. (An outline of the data elements collected, broad definitions for each data category, and a listing of possible data sources is available on request.)

Within each participating organization, a survey data coordinator was designated to collect and enter information about the organization's experience for each surveyed area. Data coordinators were encouraged to complete the survey using an Internet version of the instrument.

Once the data were submitted, they were subjected to validity checks and were then standardized across participants in the study. After this process was completed, each organization's data coordinator was sent a data quality report outlining questionable results found during the initial quality tests, and further clarification was requested.

A second series of tests focused on standardizing and displaying the calculated measures to be reported in the study. To standardize the database across participants, certain measures were created (eg, total group health plan payment per plan eligible employee, total turnover costs per active employee, EAP utilization rate, non-occupational disability days absent per eligible employee, workers' compensation incidence rate, and health promotion program utilization and costs per eligible employee). Each organization's metrics were then subjected to another series of validity tests that compared their experience with that of other respondents. An acceptability range was established for each measure. If a respondent's results were questionable, further investigations were conducted. A second data quality report card, which outlined questionable calculated metrics, was then sent to



The sum of median 1998 HPM costs across programs was \$9,992 per eligible employee.

Fig. 1. Median HPM costs per eligible employee for all survey participants. Reprinted with permission from the *American Journal of Health Promotion*.

each organization's data coordinator for final clarification.

After this series of validity checks, a determination was made as to which reported data were sufficiently credible and within acceptable range and could therefore be pooled for the purpose of establishing benchmarks. For most measures, reasonable minimum and maximum values were identified and 25th percentiles, medians, and 75th percentiles were calculated.

When reporting most aggregate metrics, the median values were used (rather than averages). This was done to minimize the effects of extreme (very high or very low) values and to prevent the results from being dominated by participants with the largest number of employees.

Once the data were analyzed, a potential HPM opportunity for improvement was calculated based on a comparison of the organization's actual performance level for a given program metric as compared with the best-practice level, which was operationally defined as the 25th percentile value for all respondents. If an organization's performance relative to a given metric was at or more favorable than the best-practice (25th percentile) level, it was designated as a best-practice organization.

Study Sample

Forty-three employers participated in the 1999/2000 benchmarking study by contributing their HPM data to the database. (A list of participating organizations is available on request.) The represented industries included communications ($n = 5$); electronics and computers ($n = 2$); finance and insurance ($n = 4$); government and education ($n = 10$); manufacturing ($n = 8$); mining, oil, and gas ($n = 2$); pharmaceutical ($n = 2$); retail trade ($n = 2$); services, transportation, and utilities ($n = 1$ for each); and other ($n = 5$). Approximately 950,000 workers were employed by the participating organizations. Almost half (48%) were salaried and the rest (52%) were hourly workers. Their average age was 42 years and the percentages of women and men were 36 and 64, respectively. Employers were well distributed nationally, with their three largest employee concentrations in 26 states. Employee job classification categories were also well distributed: professional (24%), laborers (23%), managers (19%), clerical (13%), services (6%), technicians (5%), and other (10%).

Results

Quantitative Phase

Overall HPM expenditures. For the calendar year 1998, the median total HPM cost per employee per year was \$9992. These dollars included HPM costs for five core program categories: group health, turnover, unscheduled absence, non-occupational disability, and workers' compensation. Group health costs constituted the largest proportion of total HPM costs (\$4666, or 47%), followed by turnover (\$3693, or 37%), unscheduled absence (\$810, or 8%), non-occupational disability (\$513, or 5%) and workers' compensation (\$310, or 3%) (Fig. 1). When other programmatic areas such as EAPs, health promotion, occupational medicine, safety, and work/life were added, total HPM costs increased to \$10,365 per employee).

The potential cost savings across the five core HPM program areas was estimated to be \$2562 per employee per year, or 26% of the median total HPM costs. The potential savings were calculated as the sum of the *differences* between the median HPM costs for benchmarking participants and the best-practice levels (ie, 25th percentile) for core HPM program areas.

Program-specific HPM expenditures. Table 1 summarizes the data for each of the core program areas examined in the study. Reported in the table are the minimum, maximum, 25th, 50th, and 75th percentile values for key utilization and cost measures.

Not shown in the table are results from the sub-analyses performed by program area. For example, in the area of group health, participant costs were highest for indemnity plans (\$4690 per eligible employee) and lowest for HMO plans (\$3946 per eligible employee). The median cost per employee for non-occupational short-term and long-term disability programs were \$370 and \$133, respectively. For workers' compensation, the median cost per em-

TABLE 1

Key Utilization and Cost Measures Collected From HPM Benchmark Study Participants, by Category—1998 Data

HPM Program Categories	Min	Max	Percentiles		
			25	50	75
Group health \$/eligible	\$3,127	\$ 6,421	\$4,049	\$4,666	\$4,978
Non-occup disab \$/eligible	\$ 225	\$ 1,084	\$ 370	\$ 513	\$ 682
Work comp \$/eligible	\$ 93	\$ 863	\$ 190	\$ 310	\$ 505
Unscheduled absence \$/eligible	\$ 131	\$ 1,864	\$ 375	\$ 810	\$1,207
Unscheduled \$/eligible, hourly	\$ 137	\$ 859	\$ 312	\$ 442	\$ 510
Unscheduled \$/eligible, salaried	\$ 308	\$ 1,337	\$ 440	\$ 868	\$1,272
Total absence rate	0.18	3.95	0.76	1.72	2.64
Absence rate, hourly	0.43	7.25	0.92	1.02	1.92
Absence rate, salaried	0.60	2.08	0.71	1.32	1.94
Total turnover \$/eligible	\$1,826	\$10,317	\$2,446	\$3,693	\$6,284
Turnover \$/eligible, hourly	\$ 848	\$ 7,986	\$2,147	\$2,595	\$3,929
Turnover \$/eligible, salaried	\$1,684	\$16,241	\$3,344	\$5,240	\$6,887
Total turnover rate	2.21	46.01	6.18	8.54	15.26
Turnover rate, hourly	5.54	64.52	10.83	17.83	25.64
Turnover rate, salaried	2.23	30.63	5.79	9.29	10.39

ployee was \$310. Participants reported that their employees were absent from work (for unscheduled or “incidental” absence) on 1.7% of scheduled workdays. The median cost for these absences was estimated to be \$810 per employee per year.

Across all employee groups, the annual turnover rate ranged from 2.2% to 46.0%. We adjusted turnover rates on the basis of the percentage of vacated positions each organization intended to fill. Then, using estimates of turnover costs obtained from a review of the literature, we calculated turnover costs for each organization. (Turnover cost estimates for hourly employees were derived from *Business and Health*, April 1998, p.10, and for salaried employees from *Workforce Magazine*, August 1997, p. 50.)

Turnover costs for hourly and salaried workers were estimated at 50% and 100% of annual base compensation, respectively. Turnover costs included expenses related to recruitment efforts, lost productivity while searching for replacement workers, and reduced productivity for new employees who require training and guidance to achieve performance levels that match those of former workers. Using these figures, the costs per employee related to turnover ranged from \$1826 to \$10,317.

Qualitative Phase

In 1998, site visits to best-practice HPM employers resulted in the formulation of 10 themes that were common to most of the organizations visited, as summarized below:

1. *There was an alignment between HPM and the overall business strategy of the organization.* HPM team members recognized that the main business purpose of their organization was to deliver products and services that are competitive in the market. The HPM team’s role was to support the organization’s primary mission by acting as a strategic partner to help the organization attain its business objectives.

2. *There was an interdisciplinary team focus.* During site visits, best-practice companies brought together staff from many diverse functional areas, such as human resources, employee benefits, risk management, employee assistance, safety, legal, labor relations, disability management, medical–occupational health, employee relations, work/life, attendance management, health promotion, quality, and security. These individuals worked cooperatively across their companies’ territories, “silos,” and “fiefdoms” to achieve common HPM and organizational goals.

In most cases, HPM teams decided that a top-heavy infrastructure was not always necessary. Although some companies restructured to create a formal interdisciplinary HPM group, many more experienced internal obstacles that kept HPM-related components apart from one another. Nonetheless, managers collaborated with one another despite organizational barriers that may otherwise have set them apart. Department or function leaders did not need to be convinced that there was a need for an interdisciplinary approach; they were already sold on this concept.

3. *There was a champion or a team of champions.* At each meeting, it was evident that one person or a group of key individuals drove the process and championed the HPM vision at all levels of the organization. These individuals exhibited the determination to make things happen and an overwhelming sense of purpose and passion about HPM.

4. *Senior management and business operations were key members of the team.* Although in many cases, an HPM approach developed as a grassroots initiative, senior management and operations leaders quickly became engaged. They recognized that an HPM model needed to be supported by senior management and throughout business operations. At

companies with successful HPM programs, the links to finance and funding sources were apparent. Senior management, business operations, and the HPM team worked hand-in-hand with an appreciation of the other's contribution to the process.

5. *Prevention, health promotion, and wellness staff were heavily engaged in the process.* These individuals believed in and practiced healthy lifestyles, employee empowerment, and self-responsibility. They advocated the establishment of a "healthy company" culture. Health promotion leaders, and their supporters in medical and occupational health departments, were able to clearly articulate the link between employee health and wellness and the productivity of the organization as a whole. They drove the research and outcome studies that documented the relationship between health and productivity for their organization.

6. *The emphasis was on quality-of-life improvement, not just cost cutting.* Repeatedly, managers talked about improving organizational processes and "doing the right thing" for their employees. There was an expectation that if an organization improved the quality of work life, productivity would also improve and cost containment would be a natural consequence. The HPM team focused not only on managing the 20% of employees who consumed most of the program resources, but also on attending to the needs of the other 80%, whose health and well-being influenced their work.

7. *Data, measurement, reporting, evaluation, and return on investment studies became increasingly important over time.* Although high costs may drive the initial HPM initiative, in most instances evaluation protocols and elaborate data-reporting systems are not prepared ahead of time. The philosophy of the HPM team seemed to be "just do it, and develop the ability to evaluate results later." Leaders decided to launch projects that were likely to quickly

improve efficiency, quality, and cost. Once actions were taken, these organizations realized that they needed to show quantitative results and develop systems for the ongoing monitoring and tracking of progress.

Data and reporting systems were developed with three main purposes in mind: (1) to highlight areas for potential intervention and improvement so that priorities could be set and the potential for savings could be quantified; (2) to provide ongoing reporting and data monitoring to the business units to hold them accountable for improved performance; and (3) to evaluate outcomes, return on investment, and potential areas for further investment.

8. *Communication was constant and was directed throughout the organization.* HPM leaders realized that they needed to keep their activities on the front burner for all constituents. They needed to communicate purpose, tactics, and results to fellow team members, business operations, the front line, and senior management. The packaging of information was critical. It needed to be organized in such a way that the target audience would understand and apply the information. The audience needed to see the purpose of HPM initiatives and realize that positive results were central to business success.

9. *There was a constant need to improve by learning from others.* To remain on the leading edge, these best-practice organizations strove to learn new ideas and approaches from others through a variety of techniques, including benchmarking. They also felt comfortable in openly sharing their experience and stories with others as a way of teaching and coaching. There was little guardedness or embarrassment about failures or mistakes; some felt they often learned more from failures than from successes. These organizations were proud of their accomplishments and enjoyed the spotlight that uncovered both their achievements and unsuccessful risk-taking initiatives.

10. *The team was having fun.* HPM team members appeared to be excited, enthusiastic, and motivated by their work. The atmosphere during the meeting was one of positive energy, and ample opportunities were available for introducing humor and good-natured challenges to fellow team members.

Discussion

As used here, benchmarking is the process of identifying, understanding, and adapting outstanding practices from best-practice organizations to help other organizations improve their performance. Employers participating in benchmarking activities report breakthrough improvements that result in cost control, improved quality, and enhanced profitability. Rarely have programs that focused on health, disability, absence, and turnover been associated with the achievement of these corporate objectives. However, there is an increasing awareness that these programs may play a significant role in achieving improved organizational productivity and, for commercial enterprises, increased profitability.

A first step in establishing the link between health and productivity is determining which baseline measures are central, germane, and likely to be broadly accepted by the employer community. In response to an identified need, the Consortium Benchmarking Study designers initiated a broad assessment of employer health and productivity measures. A central objective of this effort was to expand the way in which most employers traditionally viewed their health and human resource programs and related costs—one program or department at a time. We aggressively sought to include a variety of areas related to health and productivity that are commonly viewed as cost centers within an organization. Using common-denominator metrics, we combined a variety of HPM program experiences into a total organiza-

tional view and repositioned the costs for these programs as corporate investments in the health and productivity of the workforce. The challenge to the study designers was to develop a finite but meaningful set of measures, ensure that data collected for these measures were credible and consistently reported across the participants, and present results that could be used as a catalyst for action.

One key exhibit in the report uses a single dollar bill icon to depict an apples-to-apples comparison of costs across core HPM programs. The total aggregate amount represented by the dollar bill can be used to effectively communicate to senior management the considerable sums already invested in HPM programs. From that point, it is a small jump to the idea that better coordination and management of these programs could reduce costs and enhance health, productivity, and quality of work life. By highlighting areas for improved coordination across programs, it becomes apparent that such an integrated approach is not only theoretical but also practical. The qualitative study findings further highlight how specific companies were implementing HPM models and the success that they were able to achieve.

For the 1999/2000 study sample of 43 employers, annual costs were \$9992 per employee for their core HPM programs that included group health benefits, absence, non-occupational disability, workers' compensation, and turnover. We also calculated that approximately \$2562, or 26% of those costs, might be saved if these organizations were able to achieve best-practice levels of performance through better coordination and management of their HPM programs. Further, we provided some insights as to how best-practice organizations implemented their HPM programs.

One might question the precision of some aggregate HPM cost figures reported here because of the significant challenge faced in gathering and comparing dollar

amounts and other metrics that vary across programs and across organizations. Moreover, within the HPM benchmarking study, we did not address the issue of low productivity while at work. However, the most important findings of the study are that HPM costs are huge, they are not limited to medical expenditures, they can be a significant financial drain for employers and their employees, and they represent a significant opportunity for quality-of-life improvement and cost savings. Our aim was to make employers more aware of their total HPM expenditures and to push them toward better management, increased coordination, and greater synergy across functional areas. Many leading organizations believe that in the near future, such an approach will become the norm (rather than merely an option), given the realities faced by employers.

One might also question the selection of the difference between actual experience and the 25th percentile as the rationale for calculating the magnitude of the opportunity for HPM improvements and savings. We chose the 25th percentile because it seemed achievable. In reality, expenditures in some areas (eg, health promotion, prescription drugs, EAP programs, mental health treatment, work/life programs) may need to be *increased* to achieve overall HPM cost reduction and productivity enhancement. In future investigations, it would be interesting to differentiate between HPM programs that are primarily investments in employee health and well-being and those that can be viewed as expenses resulting from the failure to invest in building and maintaining productive human capital.

We are too early in our investigations to precisely estimate the impact of individual program changes, not to mention aggregate HPM program changes, on an organization's productivity. Nevertheless, to begin the discussion, we

chose the 25th percentile as a credible and achievable target for performance improvement. Individual organizations should examine the management of their HPM programs and work with their vendors and internal staff (from multiple departments) to identify their realistic potential for cost savings.

An important lesson strongly supported by the results of the HPM benchmarking study is that a broad approach is needed to manage HPM-related costs. Narrowly focused programs influencing only medical costs are not sufficient; these programs account for less than half of the HPM dollar. The next level of investigation is to identify which models are best suited for introducing and maintaining HPM programs and the relative success of these programs.

We are poised to begin what has been termed by some as the next and most important paradigm shift for American businesses in the areas of health care benefits and human resources (Sullivan S. Remarks delivered at the HPM Consortium Benchmarking Meeting, Dulles Airport, Washington, D.C., March 29, 2000.) Although some employers are ready to divest their responsibility for providing health benefits to their employees (reflected by a rising interest in defined contribution plans), others are convinced that they can exert a substantial influence on their organization's performance through focused investment in health and productivity management. The results of the benchmarking study support the efforts made by employers who are convinced that they can make a significant difference in their organization's performance by improving the health and well-being of their workers.

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Future Car Electronics Power

People are spending increasing amounts of time in their cars. As a result, automakers are equipping vehicles with more and more power-draining creature comforts as selling points (eg, navigational systems, front and rear passenger climate controls, compact disc players). But performance and handling improvements under the hood, such as dynamic stability controls, electronic suspensions, etc, also need power from the 14-volt system featured in today's cars. To handle the situation, automotive manufacturers are embracing a 42-volt standard for system voltage as they design new products. The challenge for designers is that the cost of the new electronics cannot prohibit the economic production of automobiles. This hurdle must be cleared before cars with 42-volt systems will become available to consumers.

Today, the average 14-volt load is between 750 watts and 1 kilowatt, with peak loads of up to 2 kilowatts, depending on the car and its accessories. By 2005, peak loads as high as 12 kilowatts will be commonplace. . . . With electronic controls in a 42-volt system costing in the range of 5 to 10 cents per watt (or \$50 to \$100 per kilowatt), instead of the current 1.2 to 1.3 cents, automakers are eager to see the costs of such systems come down.

—From Kassakian JG, Miller JM, Traub N. Automotive electronics power up. *IEEE SPECTRUM.* 2000;37(5):34–39.