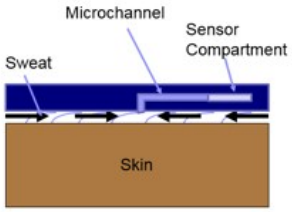
Supplementary Section

A. *Sweat Dynamics and Sensor Lag*



- Sweat fills the gap 1st, then it flows laterally to the micro-channels & sensors
- Minimize lag time by minimizing separation between the microfluidics and the skin
- Sensor temporal resolution is limited by the distribution of sweat "ages"

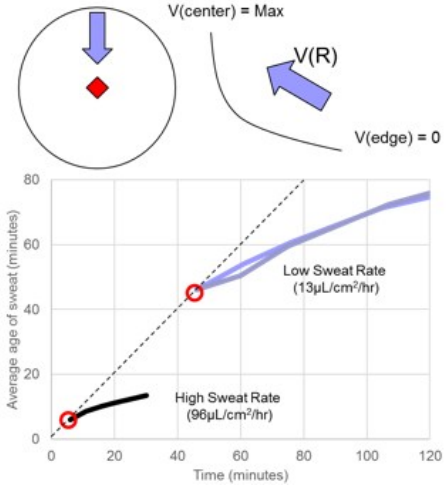


Figure S1: Sweat dynamics and lag time between sweat secretion and arrival to the sensing site

B. *Materials down-selection for fabrication of the fluidic chamber*

We considered multiple materials to generate the functional (e.g., fluidic) and structural (e.g., adhesive) layers of the microfluidics module. We performed material compatibility testing with simulated sweat (dyed red) to determine the appropriate materials for building the self-priming chamber of the fluidic module. Initially, two pressure sensitive adhesive (PSA) formulations (3M and Advanced Research (AR)) were tested with two PET films (AR hydrophilic, and Tekra ST505 Melinex®) with 3M Tegaderm (non-adhesive side) forming the fourth wall of the capillary to mimic the design of the device. In each combination, four parallel 2mm wide capillaries were cut from the PSA, adhered between the PET and Tegaderm, cut to expose both ends and tested for self-priming capability via contact with a droplet of red-dyed simulated perspiration. The results of the test are shown in Figure S2-a), with the conclusion that the combination of Tekra PET and 3M Tegaderm is not sufficiently hydrophilic to enable self-priming flow (independent of the PSA in use). An alternate design incorporating the Tekra and AR PET materials (with AR adhesive between them) was tested. This film combination also showed self-priming capillary flow and could be used in the device, as shown in Figure S2-b).

a

Top Film	PSA	Base Film	Flow
Tekra Melinex ST505	3M 8172	3M Tegaderm	N (4/4)
ARFlow	3M 8172	3M Tegaderm	Y (4/4)
Tekra Melinex ST505	AR PSA	3M Tegaderm	N (4/4)
ARFlow	AR PSA	3M Tegaderm	Y (4/4)
Tekra Melinex ST505	3M 8172	ARFlow	Y (4/4)

b

Figure S2 a) *Table of results of testing Film/PSA combinations for self-priming capability with non-priming compositions highlighted in red.* ***b)*** *photograph of one such combination which successfully self-primed with red-dyed artificial perspiration (in this case ARFlow, 3M 8172 PSA & Tegaderm).*

To test the performance of the sweat resorvair, two 5-wick-chamber patches were assembled without valves or sensors, including a patch of GE Healthcare Whatmann Standard 17 glass fiber containing dried food dye (green or blue) cut to fit the sensor fluidic volume (to enable easy visualization of sweat movement). These patches were worn during moderately intense cycling outdoors in 85°F, 40% RH for a total of 1 hour, with access to hydration (water) as needed, as a model for high exertion activity. One patch was worn on the lower left of the back (over the latissimus dorsi muscle and thoracolumbar fascia) and the other was worn on the back of the left lower leg (over the gastrocnemius muscle group). In both cases, the skin area below and surrounding the patch application point was shaved prior to application. The rider stopped approximately every 15 minutes to photograph the patches and made note of the fluid progression at intermediate timepoints, and reported on the wearability/feel of the patches as well. The results of this pilot study were A) that the patches were noted to be quite comfortable and did not impede motion or draw attention to themselves during use, B) the time from starting exercise to sweat passing through the detection area (in this case filled with a dye-laden wick) was approximately 8 minutes on the leg and <18 minutes on the back (back was only checked during stops), C) even without valves, the multiple wick design showed largely sequential filling of wicks one-by-one based on the capillary driving force of the wick pulling sweat in until the first-wetted wick had filled, at which point the next began filling, and D) the initial Standard 17-based wick design proved to be too low volume for high exertion activity (filling up completely on the leg during 1 hour cycling) and a higher volume wick material was chosen for subsequent designs. A photographic record of the lower leg patch is shown in Figure S3. Similar, though quantitatively slower filling results were seen for the lower back (likely due to the higher exertion of the lower leg muscles vs. those of the lower back during cycling).

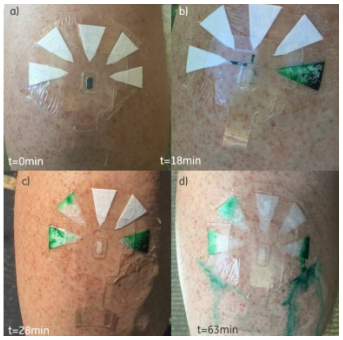


Figure S3*- Photographic progression of leg-worn sweat patch filling with sweat during exercise*

C. Laboratory test system

For laboratory testing, the sodium ISEs embedded in the fluidic structure or as stand-alone sensors were put in direct contact with a skin mimicking interface. This interface consisted of a 50-60 µm thick porous rayon film with average pore size and pore density similar to those of human skin, and was connected to a programmable precision syringe pump for on-demand delivery of artificial sweat or chloride salt solutions. This system is then fluidically coupled to the patch using a PSA gasket. The test system also included a micro flow-meter (with a resolution of 0.5nl/min resolution) to measure the flow rate across the skin mimicking interface and a notebook computer set up to wirelessly receive the sodium ion concentration data from the Shimmer board electronics module (See Figure S5). It should be noted that for simplicity purposes in some experiments the sweat collector assembly used on-body to channel the sweat collected from a selected area of skin was omitted and the syringe assembly was directly connected to the inlet port of the sensor fluidics (hole in Tegaderm layer).

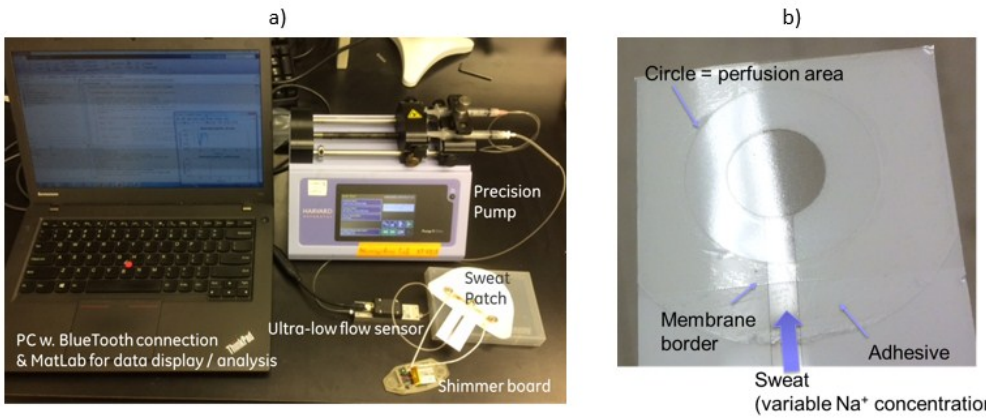


Figure S4- a) *Lab based sweat testing system with notebook, syringe pump and flow sensor,* ***b)*** *Skin mimicking interface using permeable membrane and microfluidics channel for sweat or salt solution delivery*

D. Sweat Composition Changes in Monitoring Device

- ISE was covered by 50µm thick skin mimicking rayon film
- 0.01M NaCl solution was dropped on top and left to evaporate at room temperature
- The potential shift illustrates what happens if sweat is left in contact with the ISE and left to evaporate

Figure S5*- Changes in the response of a stand-alone* Na^+ *ISE (which did not include the microfluidics module) exposed to a 0.01M NaCl solution over a one-hour period.*

References

1. D. J. Casa, L. E. Armstrong, S. K. Hillman, S. J. Montain, R. V. Reiff, B. S. Rich, W. O. Roberts and J. A. Stone, *Journal of athletic training*, 2000, **35**, 212.
2. M. N. Sawka, A. J. Young, R. P. Francesconi, S. R. Muza and K. B. Pandolf, *Journal of Applied Physiology*, 1985, **59**, 1394-1401.
3. F. M. Williams-Bell, B. Aisbett, B. A. Murphy and B. Larsen, *Frontiers in physiology*, 2017, **8**, 815.
4. H. R. Lieberman, *Journal of the American College of Nutrition*, 2007, **26**, 555S-561S.
5. A. C. Grandjean and N. R. Grandjean, *Journal of the American College of Nutrition*, 2007, **26**, 549S-554S.
6. K. E. D'Anci, F. Constant and I. H. Rosenberg, *Nutrition reviews*, 2006, **64**, 457-464.
7. R. W. Kenefick, S. N. Cheuvront, L. Leon and K. K. O'Brien, *Dehydration and rehydration*, ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA THERMAL AND MOUNTAIN MEDICINE DIVISION, 2012.
8. C. Munoz, E. Johnson, J. Demartini, R. Huggins, A. McKenzie, D. Casa, C. Maresh and L. Armstrong, *European journal of clinical nutrition*, 2013, **67**, 1257-1263.
9. S. N. Cheuvront and R. W. Kenefick, *Comprehensive Physiology*, 2014.
10. A. Pai, K. Cardone, R. Daoui, P. Salenger, X. Chen, T. Kao, G. Boverman and D. Davenport, 2015.
11. X. Chen, T.-J. Kao, J. M. Ashe, G. Boverman, J. E. Sabatini and D. M. Davenport, *Physiological measurement*, 2014, **35**, 1137.
12. Z. Sonner, E. Wilder, T. Gaillard, G. Kasting and J. Heikenfeld, *Lab on a Chip*, 2017, **17**, 2550-2560.
13. D. P. Rose, M. E. Ratterman, D. K. Griffin, L. Hou, N. Kelley-Loughnane, R. R. Naik, J. A. Hagen, I. Papautsky and J. C. Heikenfeld, *IEEE Transactions on Biomedical Engineering*, 2015, **62**, 1457-1465.
14. G. Matzeu, C. O'Quigley, E. McNamara, C. Zuliani, C. Fay, T. Glennon and D. Diamond, *Analytical Methods*, 2016, **8**, 64-71.
15. A. Koh, D. Kang, Y. Xue, S. Lee, R. M. Pielak, J. Kim, T. Hwang, S. Min, A. Banks and P. Bastien, *Science translational medicine*, 2016, **8**, 366ra165-366ra165.
16. S. Imani, A. J. Bandodkar, A. V. Mohan, R. Kumar, S. Yu, J. Wang and P. P. Mercier, *Nature communications*, 2016, **7**, ncomms11650.
17. T. Glennon, C. O'Quigley, M. McCaul, G. Matzeu, S. Beirne, G. G. Wallace, F. Stroiescu, N. O'Mahoney, P. White and D. Diamond, *Electroanalysis*, 2016, **28**, 1283-1289.
18. W. Gao, S. Emaminejad, H. Y. Y. Nyein, S. Challa, K. Chen, A. Peck, H. M. Fahad, H. Ota, H. Shiraki and D. Kiriya, *Nature*, 2016, **529**, 509-514.
19. S. Emaminejad, W. Gao, E. Wu, Z. A. Davies, H. Y. Y. Nyein, S. Challa, S. P. Ryan, H. M. Fahad, K. Chen and Z. Shahpar, *Proceedings of the National Academy of Sciences*, 2017, 201701740.
20. J. Choi, D. Kang, S. Han, S. B. Kim and J. A. Rogers, *Advanced healthcare materials*, 2017, **6**.
21. A. J. Bandodkar, D. Molinnus, O. Mirza, T. Guinovart, J. R. Windmiller, G. Valdés-Ramírez, F. J. Andrade, M. J. Schöning and J. Wang, *Biosensors and bioelectronics*, 2014, **54**, 603-609.
22. H. Y. Y. Nyein, L.-C. Tai, Q. P. Ngo, M. Chao, G. B. Zhang, W. Gao, M. Bariya, J. Bullock, H. Kim, H. M. Fahad and A. Javey, *ACS Sensors*, 2018, **3**, 944-952.
23. A. Martín, J. Kim, J. F. Kurniawan, J. R. Sempionatto, J. R. Moreto, G. Tang, A. S. Campbell, A. Shin, M. Y. Lee, X. Liu and J. Wang, *ACS Sensors*, 2017, **2**, 1860-1868.
24. M. McCaul, T. Glennon and D. Diamond, *Current Opinion in Electrochemistry*, 2017.
25. J. Heikenfeld, *Electroanalysis*, 2016, **28**, 1242-1249.

26. M. J. Buono, K. D. Ball and F. W. Kolkhorst, *Journal of Applied Physiology*, 2007, **103**, 990-994.
27. L. B. Baker, *Sports Medicine*, 2017, 1-18.
28. C. J. Smith and G. Havenith, *European journal of applied physiology*, 2011, **111**, 1391-1404.
29. C. E. Dziedzic, M. L. Ross, G. J. Slater and L. M. Burke, *International journal of sports physiology and performance*, 2014, **9**, 832-838.
30. D. Brebner and D. M. Kerslake, *The Journal of physiology*, 1964, **175**, 295-302.
31. K. Sato, W. Kang, K. Saga and K. Sato, *Journal of the American Academy of Dermatology*, 1989, **20**, 537-563.
32. K. Sato, *American Journal of Physiology--Legacy Content*, 1973, **225**, 1147-1152.
33. T. C. Boysen, S. Yanagawa, F. Sato and K. Sato, *Journal of Applied Physiology*, 1984, **56**, 1302-1307.
34. D. Diamond, G. Svehla, E. Seward and M. McKervey, *Analytica chimica acta*, 1988, **204**, 223-231.
35. M. Alia-Novobilski, *Wright Patterson Air Force Base Press Release*, 2018, http://www.wpafb.af.mil/News/Article-Display/Article/1495074/afrl-led-patches-make-sense-of-sweat/